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THE EFFECT OF ENVIRONMENTAL FACTORS ON THE RESPIRATORY HEALTH OF SCHOOL CHILDREN IN HAMILTON

CURRENT REPORT #5

April 1, 1981

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URBAN AIR ENVIRONMENT GROUP

McMASTER UNIVERSITY

TO

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1-1	Abstract of Paper Entitled Air Quality and its Effect on the Respiratory Health of School Children: A Study in Hamilton, Ontario 1978-1981.
1-2	Abstract of Paper Entitled Airflow Obstruction in Children and its Relationship to Questionnaire Data.
1-3	Abstract of Paper Entitled Air Quality and its Effect on the Respiratory Health in Schoolchildren: A Study in Hamilton, Ontario. 1978-1981.
1-4	Abstract of Paper Entitled Effects of the Breathing Environment on the Respiratory Health of Schoolchildren in Hamilton, Ontario.
3-1	Revised Smoking Questionnaire
3-2	Abstract of Paper Entitled Single-Breath Nitrogen Washout as an Epidemiological Survey Tool in Children.
3-3	Card 3 and Card 5 - Year 3.
3-4	Protocols and Criteria to be Used by the Pulmonary Function Testers in the Schools and by the Coders.
6-1	Abstract and Reprint of Paper Entitled Very High Sensitivity Spectroscopy using Tunable Diode Lasers.

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PART 1

INTRODUCTION

This report is intended to be read in conjunction with Current Reports No. 1, No. 2, No. 3 and No. 4, dated respectively, March 1, 1979, October 1, 1979, April 1, 1980, and October 1, 1980. This report follows roughly the same format as the four previous reports, and is intended to outline progress made since Report No. 4.

In addition to the papers mentioned later in the text of this report, four others, listed below, have been submitted for presentation at various scientific meetings. Abstracts of these papers have been included as Appendices 1-1 through 1-4.

1. Appendix 1-1

   Air Quality and Its Effect on the Respiratory Health of School Children: A Study in Hamilton, Ontario.

   This paper has been accepted for presentation in a poster session at the Environmetrics '81 Conference sponsored by the Society for Industrial and Applied Mathematics in Alexandria, Virginia (April 1981).

2. Appendix 1-2

Airflow Obstruction in children and its Relationship to Questionnaire Data.

This paper has been accepted for presentation at the annual meeting of the American Thoracic Society in Detroit (May 11-13, 1981).

3. Appendix 1-3

Air Quality and Its Effect on the Respiratory Health in School Children: A Study in Hamilton, Ontario. 1978-1981.

This paper has been accepted for presentation at a poster session at the American Thoracic Society annual meeting in Detroit (May 11-13, 1981).

4. Appendix 1-4

Effects of the Breathing Environment on the Respiratory Health of School Children in Hamilton, Ontario.

This paper has been submitted for presentation at the 28th Ontario Industrial Waste Conference sponsored by the Ontario Ministry of the Environment (Toronto, June 14-17, 1981).

PART 2

QUESTIONNAIRE SURVEY

2.1 PROGRESS OF YEAR 2

Interviewing for Year 2 was concluded in October 1980. The completion rate for each quadrant has remained comparable to Year 1 as shown for the first 22 schools during Year 2 (Table 2-1, Report No. 4).

At the completion of Year 2 interviewing in schools from our original group, three further schools were added, all in the lower east quadrant. Initial inspection of the air quality gradients in this area had shown them to be particularly close; failure to recruit new schools would result in underrepresentation in the high exposure group. Table 2-1 shows the total number of interviews in each quadrant.

2.2 RE-SURVEYING OF CHILDREN FROM YEAR 1

Figure 2-1 shows the restudy rate in Year 2 of those children from Year 1. The restudy percentages are comparable to those shown in Figure 2-1 in Report No. 4. The figure also shows the number of new children in each quadrant.

2.3 VALIDATION OF QUESTIONNAIRE RESPONSES

Validity (that is, the closeness of a measure to the "truth" or underlying concept) can be measured by several methods, each of varying rigour. One way that we chose to use was designed to answer the question "Can a pulmonary function variable discriminate between those with positive and negative responses?" If so, then a positive response would seem to measure an aspect of the respiratory health of the child and strengthen confidence in the validity.

Since the derived variable FEV_1/FVC is the most commonly used index of airflow obstruction, this was used to examine the relationship between a reduced FEV_1/FVC ($< 70\%$) and a positive response to each question. Significant associations ($p < 0.05$) were found for the questions on persistent wheezing and asthma. The discriminatory value of each question was then explored further by parallel line regression analysis as shown in Figure 2-2. For both questions, there was a significant reduction in FEV_1/FVC in those with a positive response, the magnitude of the reduction increasing with age for asthma but remaining constant for persistent wheezing. This analysis, therefore, helps to validate these two questions.

Other strategies of validation involve cross-checking the question on absenteeism with absence records and the administration of a smaller questionnaire to the older children to validate the questions on parental smoking.

TABLE 2-1

INTERVIEWS COMPLETED BY QUADRANT YEAR 2

	East	West
Upper City	889	848
Lower City	1,119	737

FIGURE 2-1

COMPARISON OF YEAR 1 vs. YEAR 2

BY QUADRANT

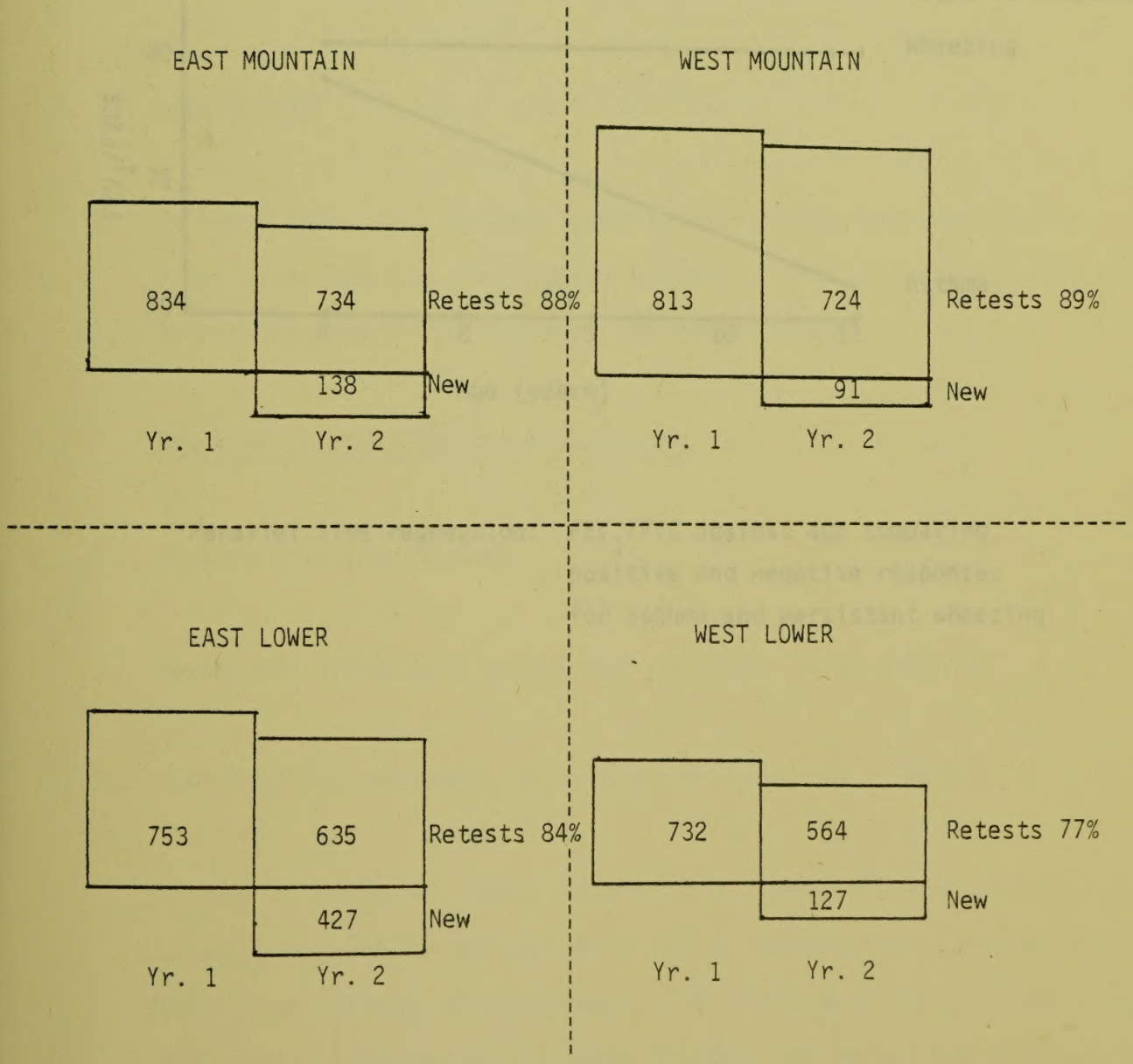
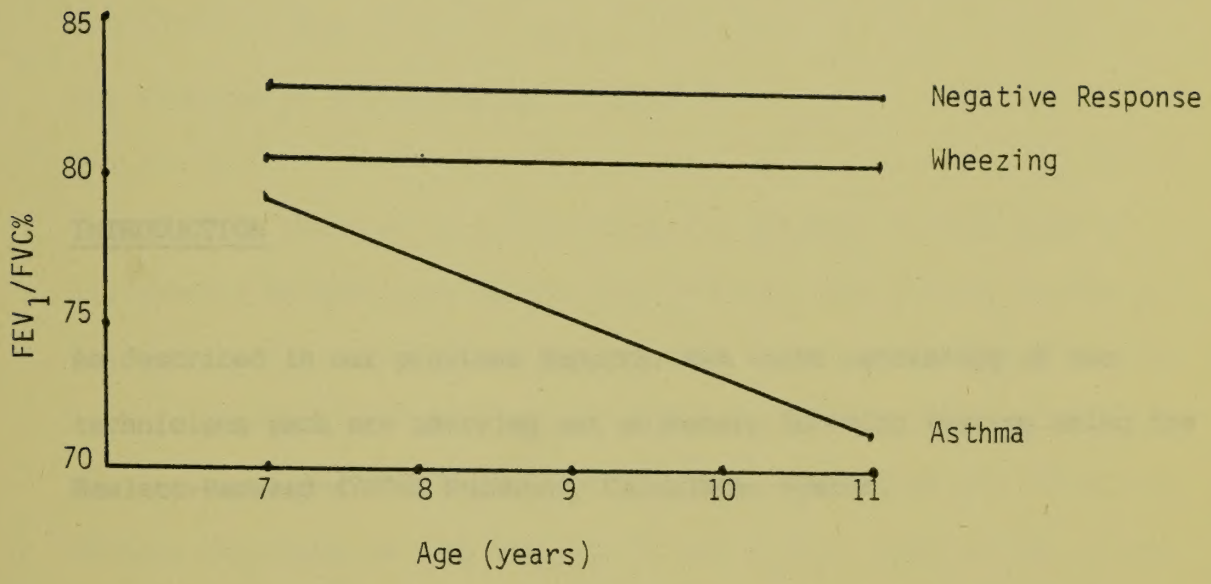
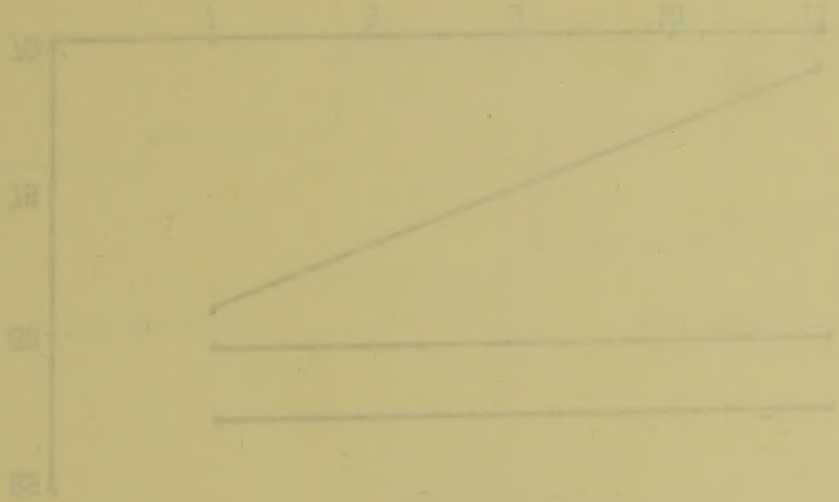


FIGURE 2-2



Parallel line regression: FEV_1/FVC against age comparing positive and negative responses for asthma and persistant wheezing



PART 3

PULMONARY FUNCTION TESTING

3.0 INTRODUCTION

As described in our previous Reports, two teams consisting of two technicians each are carrying out pulmonary function testing using the Hewlett-Packard 47804A Pulmonary Calculator System.

3.1 PROGRESS OF PULMONARY FUNCTION TESTING

3.1.1 TESTING COMPLETED TO DATE

During the second year of testing, we tested 3,439 children.

3.1.2 COMPARISON OF THE NUMBER OF CHILDREN TESTED - YEAR 1/YEAR 2

In Year 1, we tested 3,132 children. Of these, 453 were lost to the second year because they had moved out of the district. We were able to test 2,656 children for the second time. This gives us a retest rate of 85%, matching our projection quite closely. Of these, 111 were children who had moved from one school to another within our system. We

recruited 538 new children into the study by picking up those in the grades being tested, who met our age criteria. We tested a further 245 children by adding three new elementary and one senior public school to our original list. The final number for Year 2 for all schools was 110% of that for Year 1. (See Figure 3-1.)

3.1.3 THE ADDITION OF NEW ELEMENTARY SCHOOLS

From results obtained by our air sampling network, we were able to delineate a certain area of the city as having the highest levels of pollution. We realized that our original sample of schools left that area poorly represented. To correct this we approached the Hamilton Board of Education and asked if we could include three new elementary schools from that part of the city in the study. Approval was given, principals were approached and we interviewed and tested all children in grades 4, 5 and 6 at Robert Land, Gibson and Lloyd George schools. We also tested those grade 6 children who had moved from Lloyd George to Queen Mary school.

3.1.4 EQUIPMENT PERFORMANCE

As mentioned in Report No. 4, considerable problems were encountered from September 1979 to June 1980 with the reliability of one of the Hewlett-Packard 47804A Pulmonary Calculator Systems. The equipment was (and is) covered by a service contract with Hewlett-Packard. Both systems were given full preventative maintenance checks in September

1980 and January 1981, and worked satisfactorily to the end of Year 2. During that testing year, Team A lost 156 hours and Team B lost 24 hours due to equipment failure.

3.1.5 SCHEDULING OF TESTING

Scheduling is still very complex, as more children are moving into and being tested in senior public schools. The number of moves in and out of schools will continue to increase, and the length of time spent in any one school will continue to decrease. In Year 1, in 30 schools, 3,132 children were tested. There were just over 100 children per school, on average. In Year 2,in 45 schools, 3,439 children were tested, averaging 76 children per school.

3.2 CHANGES AS OF YEAR 3

3.2.1 SMOKING STATUS OF CHILDREN

The design of the questionnaire answered by the children concerning their smoking habits has been changed. This was done to eliminate some of the problems that the children had in answering certain questions and also to simplify and speed up coding procedures. See Appendix 3-1.

3.2.2 THE NWs TEST

It was decided that the single breath nitrogen washout (NWs) manoeuvre should no longer be included in our testing procedure. As was detailed in Report No. 4, this test proved difficult for the children to do, and was difficult to quantify. We also had serious doubts as to its reproducibility. Accordingly, a pilot study was undertaken at McMaster on October 27, 1980, to investigate the reproducibility of the NWs test.

Strict criteria were established for control of flow rates (more strict than used in the schools) to ensure that the test was standardized as much as possible. Tests were only accepted in which the mean expired flow did not exceed 0.3 litres/sec and peak flow was kept below 0.5 litres/sec. We tried to obtain three forced vital capacities (FVC) and three single breath washouts (NWs) from each subject. Only five of the 13 subjects, between the ages of eight and 11, were able to perform the NWs test to the new criteria . These children were then retested, giving us data from six tests on each of them.

We then established the mean, standard deviation and coefficient of variation for the following variables: FVC, FEV_1, $F_{25/75}$, PF,MET, N_2 diff, CV and CV/VC. We found that, in all cases, the coefficients of variation for all variables obtained from the NWs test were much higher than for variables obtained from the FVC test (see Figure 3-2). In other words, the reproducibility of the NWs is very much poorer than the FVC. As a result of this study, it was decided to stop using this test in the school testing program.

In order to give statistical strength to our argument, a further study was designed to be carried out in the schools. During Year 2, in four schools, repeated NWs tests were obtained from 46 children, following criteria described above. Data from this study are still being analyzed. A full description of the protocol and findings of this study will be prepared for the next report.

This study has been submitted to the Canadian Thoracic Society for possible presentation as a poster session at the June 1981 Annual Meeting in Saskatoon. The abstract prepared for this paper is included as Appendix 3-2.

3.2.3 THE NWm TEST

During February 1981, problems had been encountered when usng the Nitrogen subsystem of the HP Pulmonary Calculator System. Both systems developed a series of mini-leaks which made the validity of the results for the multiple breath nitrogen washout (NWm) questionable. Every test required careful scrutiny; often several tries were required to obtain a good test. It was noted that even when the tests seemed similar in quality, the values for FRC and IDI were often different. Therefore, it was decided to investigate reproducibility of these two functions formally. We intend to do repeat NWm measurements on 500 children during March and April 1981. Protocol and results will be included in our next current report.

3.2.4 PROTOCOL AND CRITERIA

The number of tests performed on each child have been reduced to three, with the elimination of the NWs test from the protocol.

The NWm test is done twice on each child, once at the beginning and once at the end of the testing procedure. This was begun during March 1981, and will continue until approximately 500 children have been so tested (see Section 3.2.3). The tester specifies which of the two tests is to be kept, the results of which are used for the project. The criteria for this decision are as follows:

> The selected test will have: 1) The lesser deviation from an estimated line of best fit; i.e., the least scatter. 2) The highest initial N_2 reading, where both tests are the same under criteria 1).

All other procedures and criteria relevant to Pulmonary Function Testing are unchanged from those described in Report No. 2, October 1979.

3.3 CODING

3.3.1 CODING PROCEDURES

All coding is still being done by the two Assistant Pulmonary Function Technicians working in the schools.

The quality of the coding, determined by routine quality controls as described in Report No. 3, is very good.

With the exclusion of the NWs test, the coding forms have had to be redesigned. There is now room on Card 5 for information regarding the smoking status of the child, FRC and IDI from the second NWm test and the school where testing is carried out. We need to record the last item, as with so many moved children, and the inclusion of so many senior public schools, the identification number no longer indicates the current school of testing. The new coding forms and the revised criteria and protocol sheets for year 3 are included as, respectively, Appendices 3-3 and 3-4.

FIGURE 3-1

COMPARISON OF NUMBERS OF CHILDREN TESTED YR1/YRII

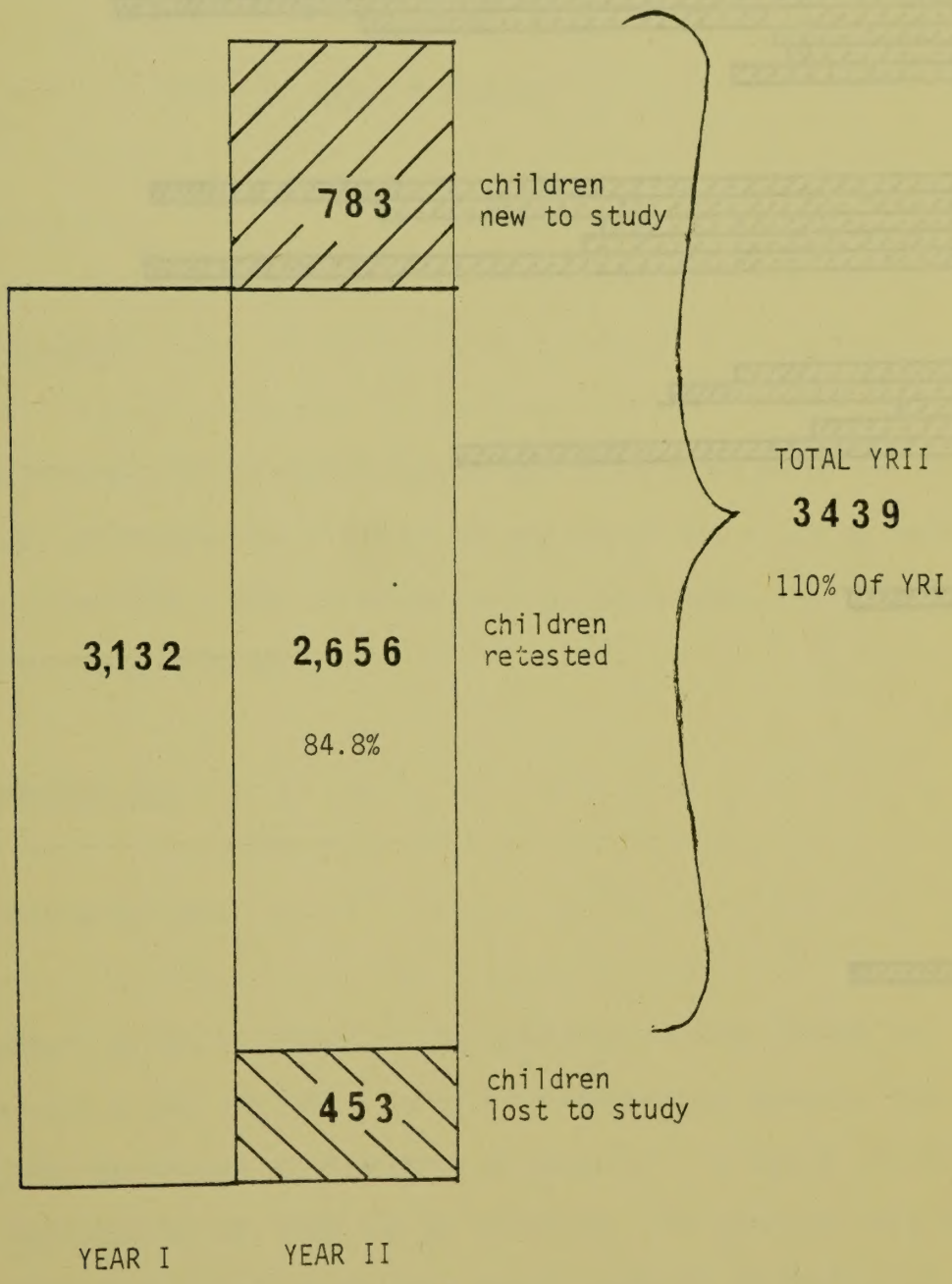
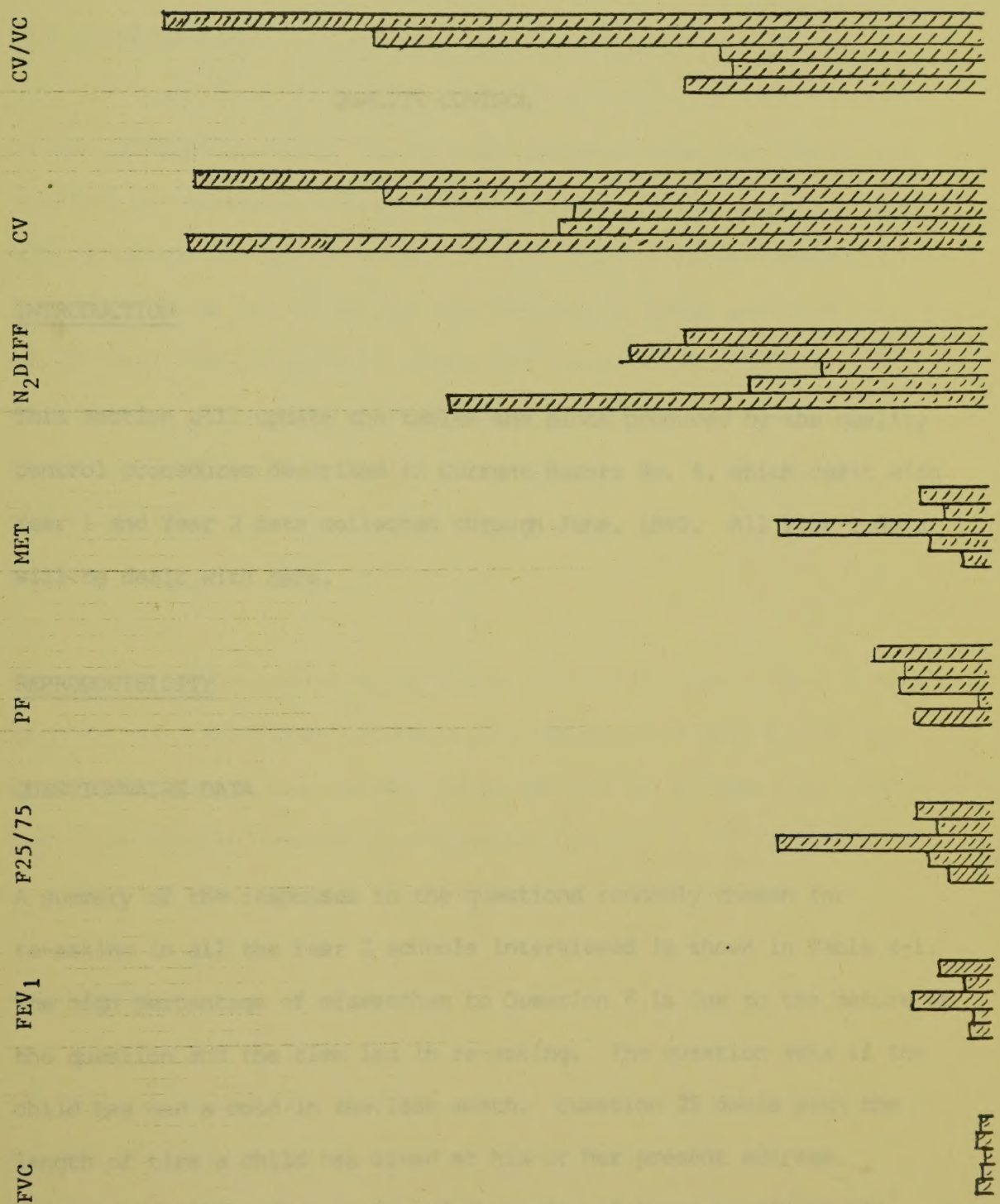


FIGURE 3-2

Comparison of Coefficients of Variation for a Number of Pulmonary Function Variables



PART 4

QUALITY CONTROL

4.0 INTRODUCTION

This section will update the tables and plots produced by the quality control procedures described in Current Report No. 4, which dealt with Year 1 and Year 2 data collected through June, 1980. All Year 2 data will be dealt with here.

4.1 REPRODUCIBILITY

4.1.1 QUESTIONNAIRE DATA

A summary of the responses to the questions randomly chosen for re-asking in all the Year 2 schools interviewed is shown in Table 4-1. The high percentage of mismatches to Question 6 is due to the nature of the question and the time lag in re-asking. The question asks if the child has had a cold in the last month. Question 25 deals with the length of time a child has lived at his or her present address. Discrepancies here are usually of the order of three to six months, which can again be explained by the nature of the question. Total

percentage of mismatches in Year 1 (10.6%) and Year 2 (11.9%) are at an acceptable rate.

4.1.2 LUNG FUNCTION DATA

As was outlined in Report No. 4, eight children from each school are selected for retesting. Table 4-2 is a summary of the paired t-tests produced using the repeat measurements of those children tested in Year 2, while Figures 4-1 to 4-6 are scattergrams of these measurements. It can be seen from the paired t-test, that at the 0.05 level of significance, FVC and FEV_1 do show a slight (0.04 litre) but significant difference.

4.1.3 CODING

The results of the coding verification done on the Year 2 data is shown in Table 4-3. Comparing the error rate obtained in Year 2 with that produced in Year 1 (see Current Report No. 3), it is seen that rates have consistantly remained at acceptable levels.

4.2 KEYPUNCHING

All data keypunched is, as before, being verified by a second operator, keeping the possibility of keypunch errors below .005%.

4.3 STORAGE

Table 4-4 contains a summary of the percent of outliers found when passing the data to be stored through range-checking programs.

4.4 EDITING

We have continued to correct all errors found when data is quality controlled.

4.5 MONITORING FOR BIAS

4.5.1 QUESTIONNAIRE

As mentioned in the previous report, a profile of each interviewer is obtained as each pair of schools is completed, according to the response rates they obtain to preselected questions. No systematic bias on the part of any one interviewer was detected as a result of the profiles produced during Year 2 interviewing.

4.5.2 PULMONARY FUNCTION TESTING

A summary of the percentage of missing values for the measurements of FVC, VC, RV, FRC, CV and N2 for the schools tested in Year 2 is found in Table 4-6. Percentages of missing values for all variables tabulated

have decreased from Year 1 (see Current Report No. 3) to Year 2. It will be noted that, although the percentage of missing CV and N_2 measurements have been considerably reduced for both teams, the test (NWs) that obtained these measurements has been removed from the testing protocol, as has been explained in section 3.2.2. Parallel line regression analysis has been used as described previously. No systematic differences between the two teams of testers appeared during the second year of testing.

4.6 SUMMARY

Under ordinary conditions, data entering most data systems contain errors. The control charts produced indicate that an acceptable error rate is being obtained, and that the data is sufficently bias free.

TABLE 4-1

QUESTIONNAIRE REPRODUCIBILITY (YEAR 2)

QUESTION CHECKED	NO. OF RESPONDENTS TELEPHONED	NO. OF MISMATCHED ANSWERS	RESPONDENT ID/ INTERVIEWER ID	NO. OF MISMATCHES / NO. OF TIMES QUESTION REASKED (%)
2	18	3	30052/11;02198/11 31078/44	16.7
25	18	9	02015/11;02152/75 02175/70;33342/56 59321/72;53345/48 57383/75;59354/72	50.0
1	28	0	-	0
17	8	3	05041/44;05054/44 06079/79	37.5
6	30	10	11024/48;12023/26 12047/11;12060/22 12072/22;12060/02 04064/52;17308/74 17322/71;18304/11	33
8	20	-	-	0
14	20	-	-	0
4	20	-	-	0
3	20	3	09187/10;09308/70 14151/56	15
25D	10	-	-	0
20	10	-	-	0
7	20	2	16023/12;21052/52	10
11	10	-	-	0
10	10	1	18304/11	10
5	10	2	20045/22;20051/22	20
25B	10	-	-	0
23	10	1	22043/56	10
25A	10	2	27014/22;27305/48	20
19	10	-	-	0
18	10	-	-	0
TOTAL	302	36		11.9%
TOTAL	236	25		10.6%

TABLE 4-2

REPRODUCIBILITY OF LUNG FUNCTION MEASUREMENTS
YEAR 2 (SCHOOLS 1 - 16, 18)

VARIABLE	NO. OF CASES	MEAN INITIAL ± SD	REPEAT ± SD	T-VALUE	P
CV/VC	228	.13 ± .20	.11 ± .09	1.04	.30
FEVI	256	1.91 ± .37	1.88 ± .39	1.99	.05
FVC	256	2.38 ± .47	2.34 ± .50	2.05	.04
MEF50	254	2.45 ± .63	2.41 ± .65	1.32	.19
RV	252	.64 ± .22	.66 ± .50	-.57	.57
MET	256	.60 ± .15	.60 ± .19	-.28	.78

TABLE 4-3

CODER QUALITY CONTROL

	LUNG FUNCTION DATA (FOR 2 CODERS)		QUESTIONNAIRE DATA
Control based on	All Year 2 Schools Tested		All Year 2 Schools Interviewed
	Card 3	Card 5	
No. of Records (5% of all ages)	150	150	197
Coding Error Rate by Column	.37%	1.39%	--
Coding Error Rate by Variable	.64%	1.1%	.13
Keypunch Error Rate	0%	0%	0%

TABLE 4-4

RANGE CHECKS

	LUNG FUNCTION DATA (For 2 Cards)		QUESTIONNAIRE DATA
Checks based on	All Year 2 Schools Tested		All Year 2 Schools Interviewed
	Card 3	Card 5	
No. of Records Checked	3446	3446	3593
Coding Error Rate by Column	.06%	.11%	.0097%
Coding Error Rate by Variable	.07%	.12%	.01%
Variables out of Range	4.4%	.86%	
Keypunch Error Rate	0%	.005%	.002%

TABLE 4-5

% MISSING VALUES FOR YEAR 2 (SCHOOLS 1-16, 17)

TEAM	TOTAL % MISSING	AGE (YEARS) 7	8	9	10	11	12	VARIABLE
		% MISSING FOR EACH AGE						
A	0.8	0.0	1.7	0.7	0.4	0.9	0.0	FVC
B	0.9	0.0	1.0	1.4	0.4	0.0	3.9	
A	1.0	0.0	2.2	1.1	0.4	0.9	1.3	VC
B	1.0	0.0	1.0	1.6	0.6	0.3	3.9	
A	2.0	0.0	3.0	2.2	1.1	2.1	4.0	RV
B	1.1	0.0	1.4	1.6	0.6	0.3	3.9	
A	16.5	33.3	26.7	16.1	13.5	11.8	28.0	CV
B	8.9	33.3	9.1	9.8	7.8	6.3	21.6	
A	1.2	0.0	1.3	1.5	0.8	0.6	4.0	FRC
B	1.0	0.0	1.4	1.6	0.6	0.0	2.0	
A	16.7	33.3	26.7	16.3	13.5	12.7	28.0	N2
B	8.9	33.3	9.1	9.8	8.0	6.3	21.6	
A	1711	3	232	546	524	331	75	TOTAL NO. OF CHILDREN TESTED
B	1728	3	287	573	528	286	51	

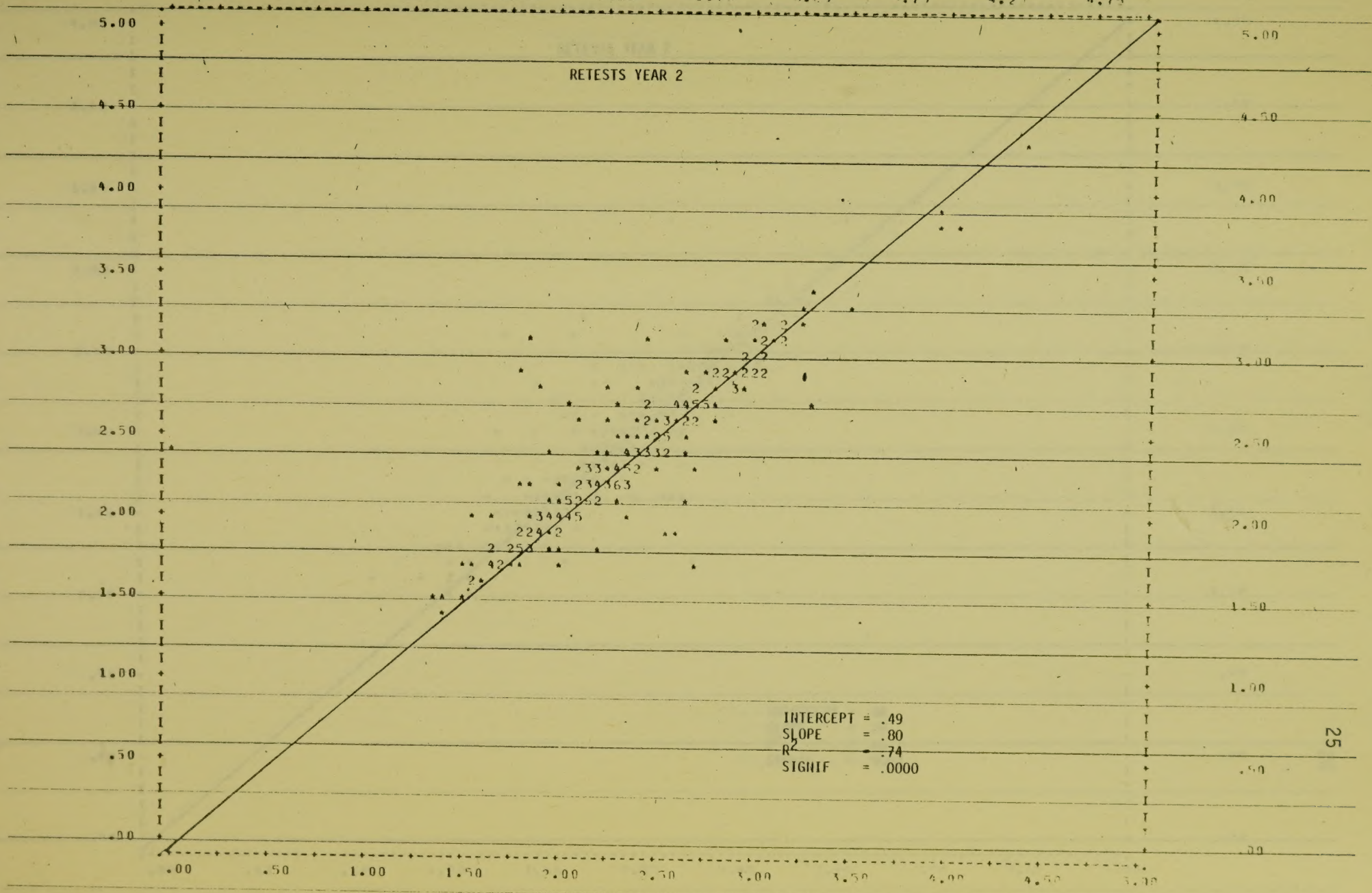
FIGURE 4-1

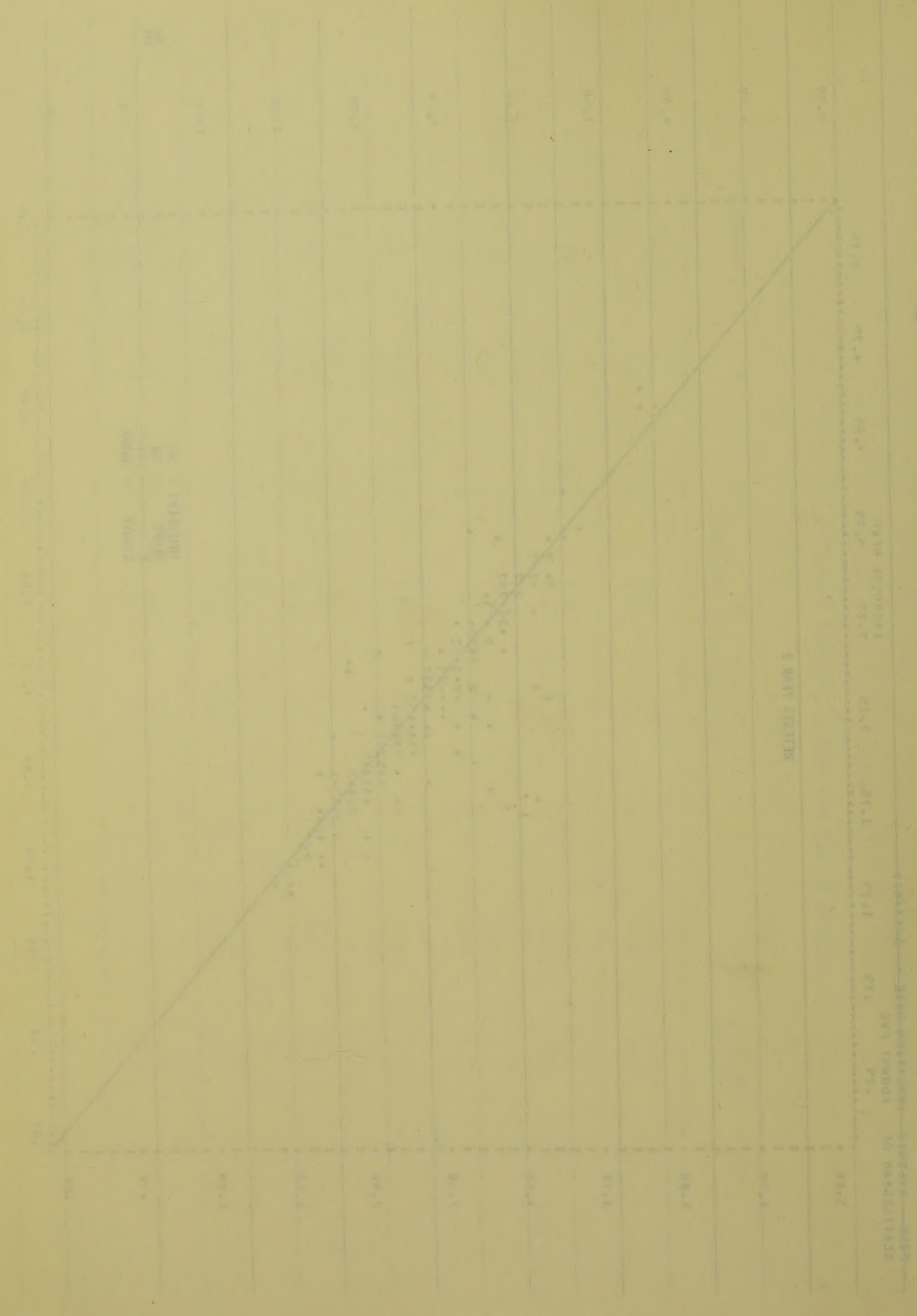
SCATTERGRAMS OF RETEST VALUES

FRI, MAR 13, 1991, 2:32 PM PAGE 6

FILE NRETST1 (CREATION DATE = 3/13/91)

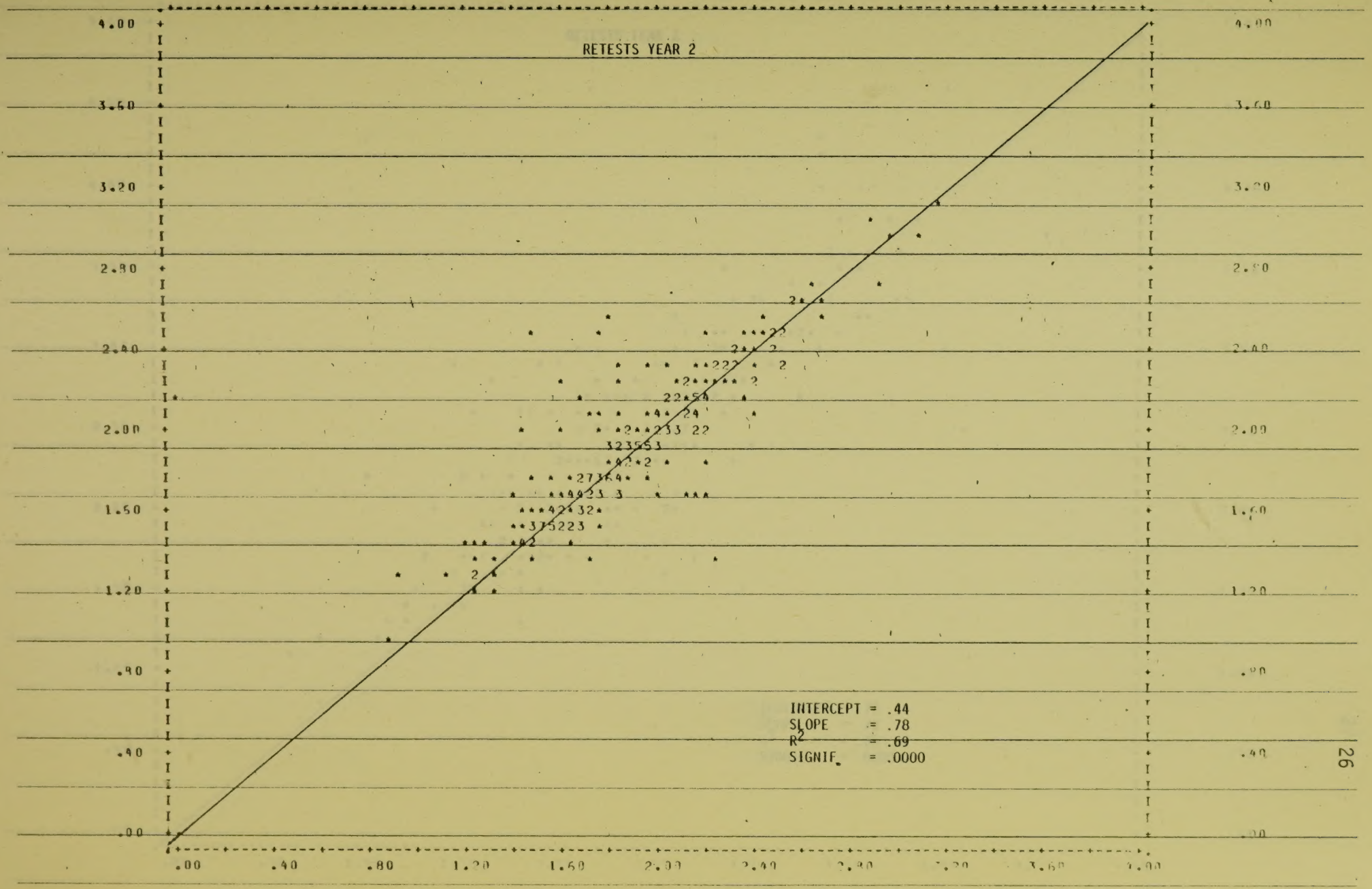
SCATTERGRAM OF (DOWN) FVC (ACROSS) RFVC





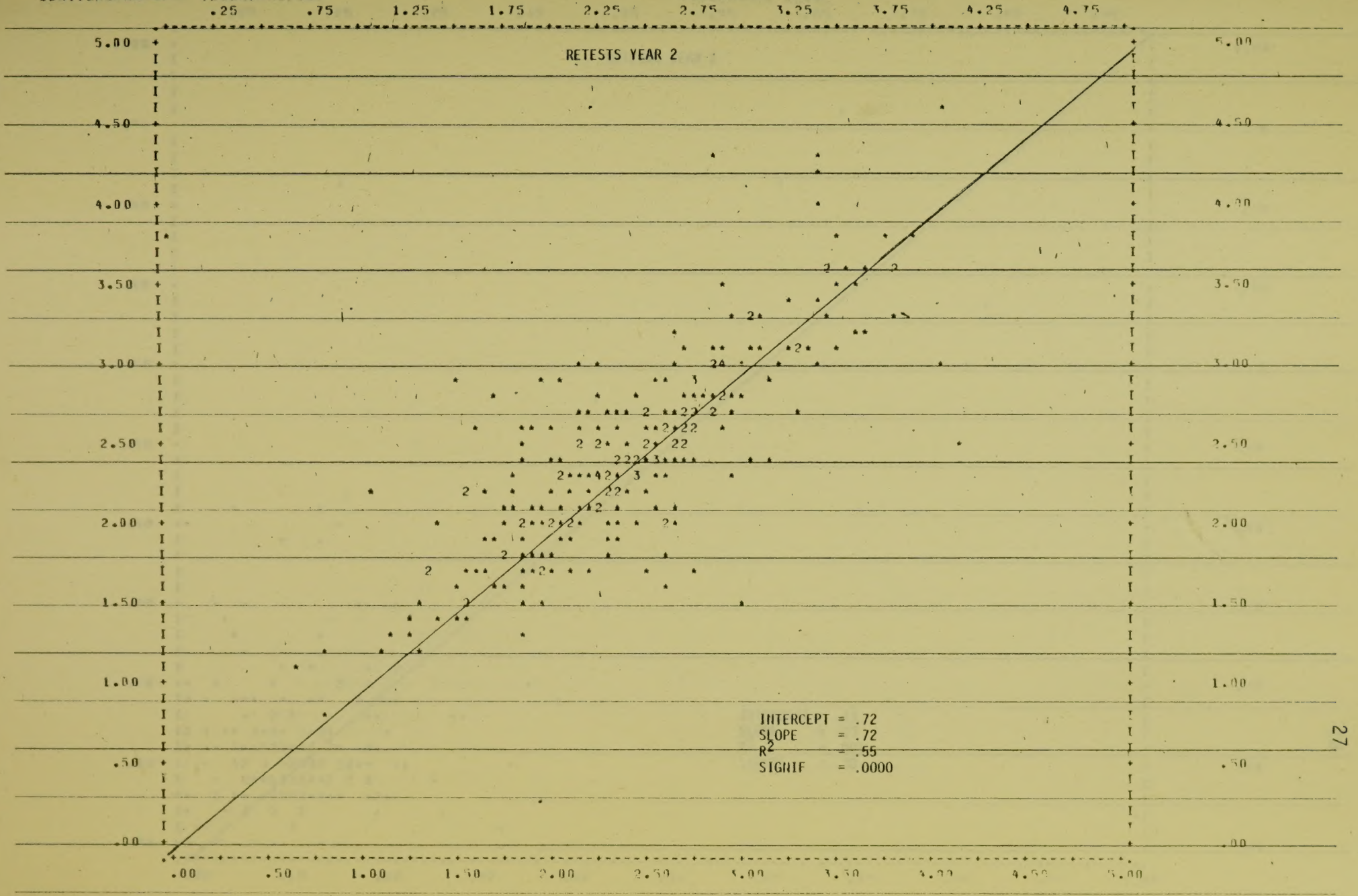
FILE NRETST7 (CREATION DATE = 3/13/81)

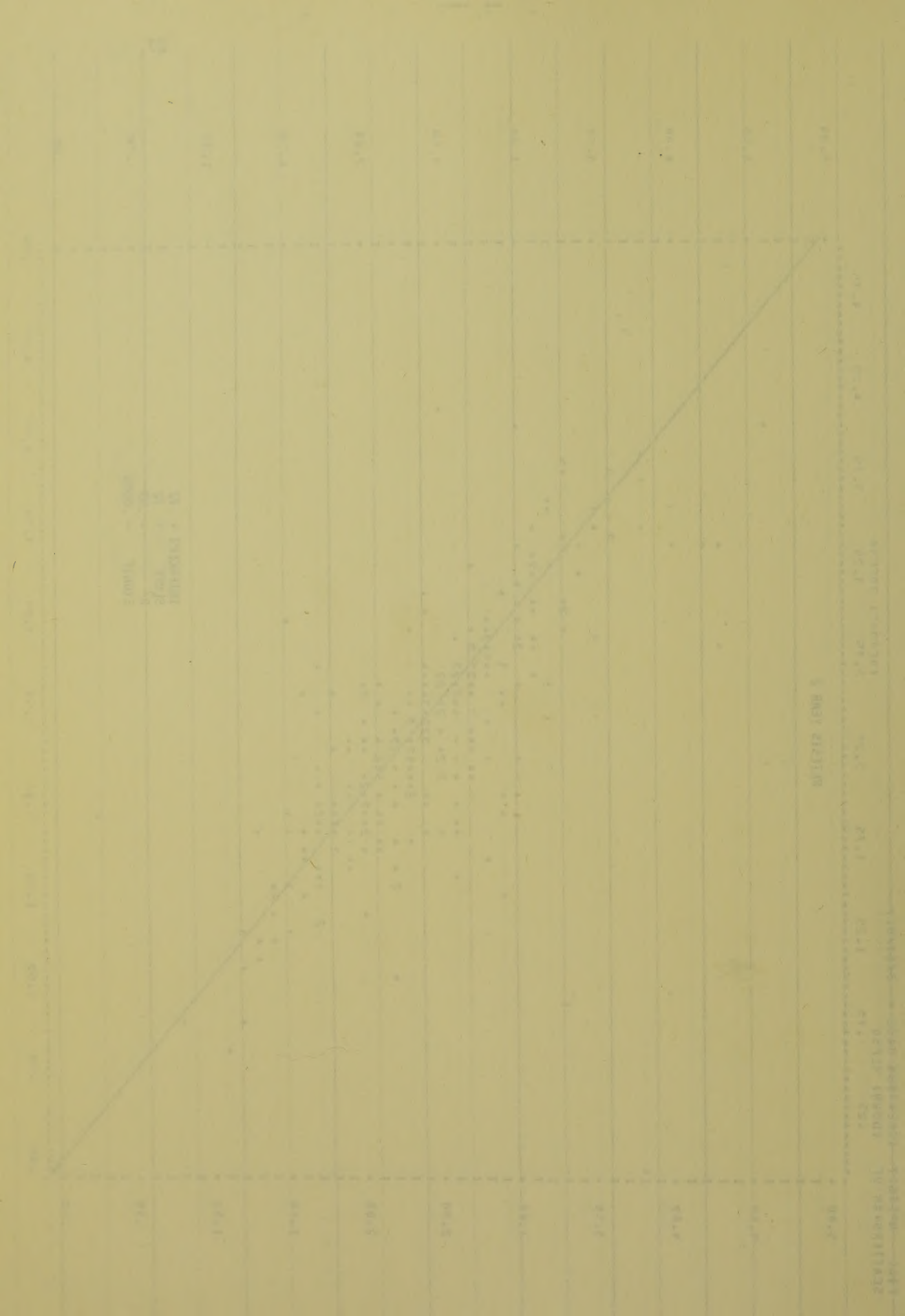
SCATTERGRAM OF (DOWN) FEV1 (ACROSS) REFV1



FILE NRETST7 (CREATION DATE = 3/13/81)

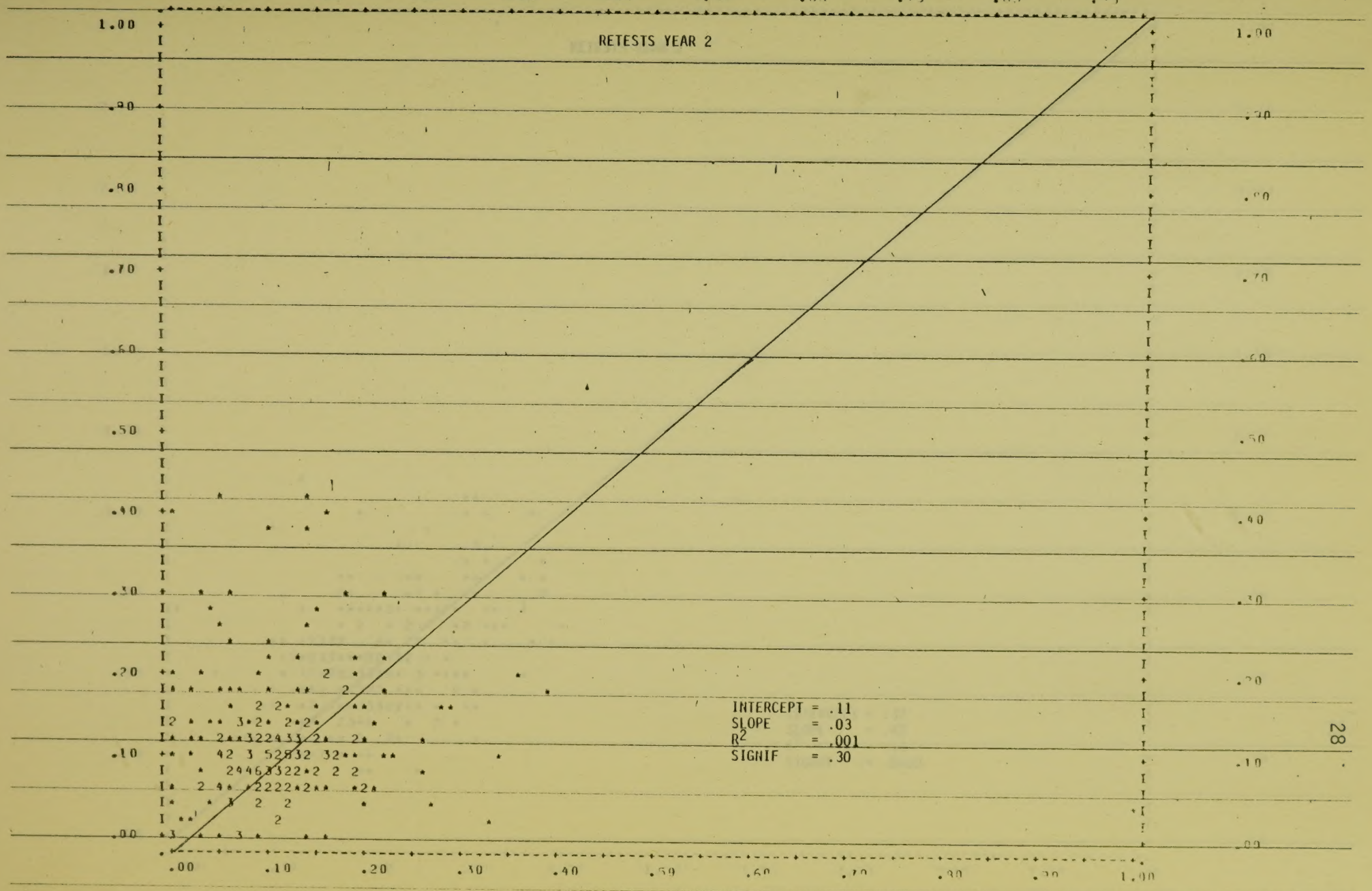
SCATTERGRAM OF (DOWN) MEF50 (ACROSS) RMEF50

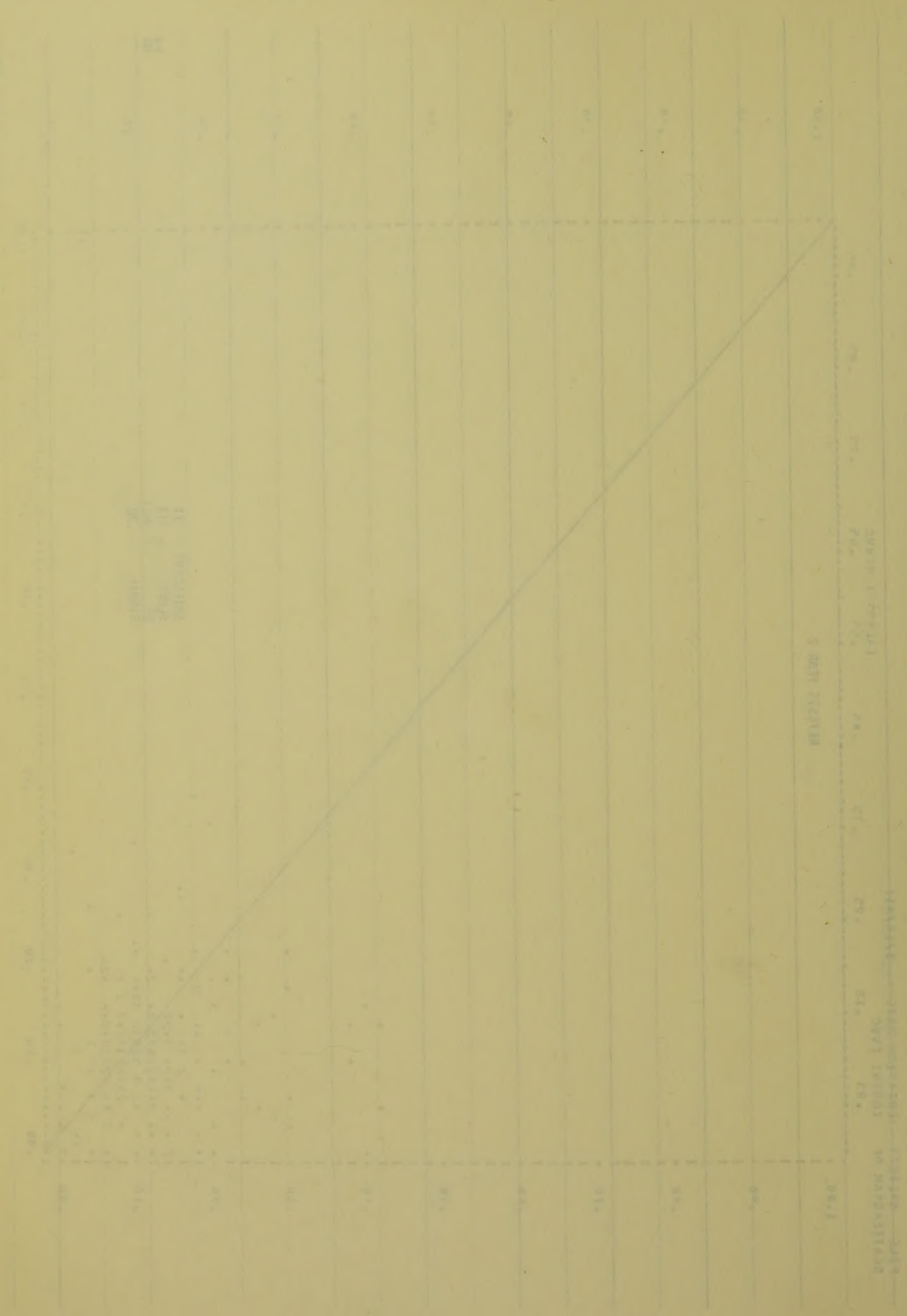




FILE NPETST7 (CREATION DATE = 3/13/81)

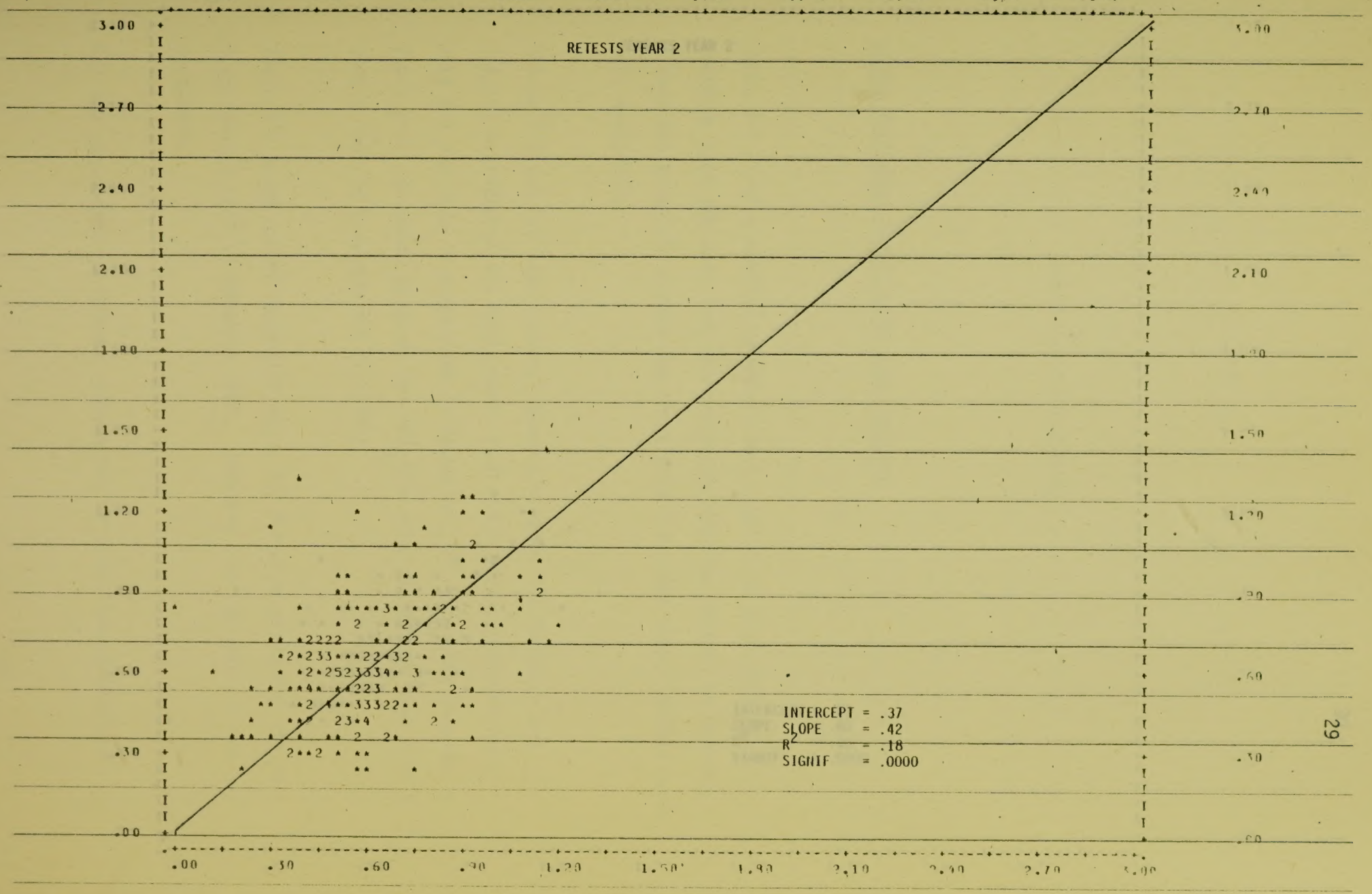
SCATTERGRAM OF (DOWN) CVVC (ACROSS) RCVVC

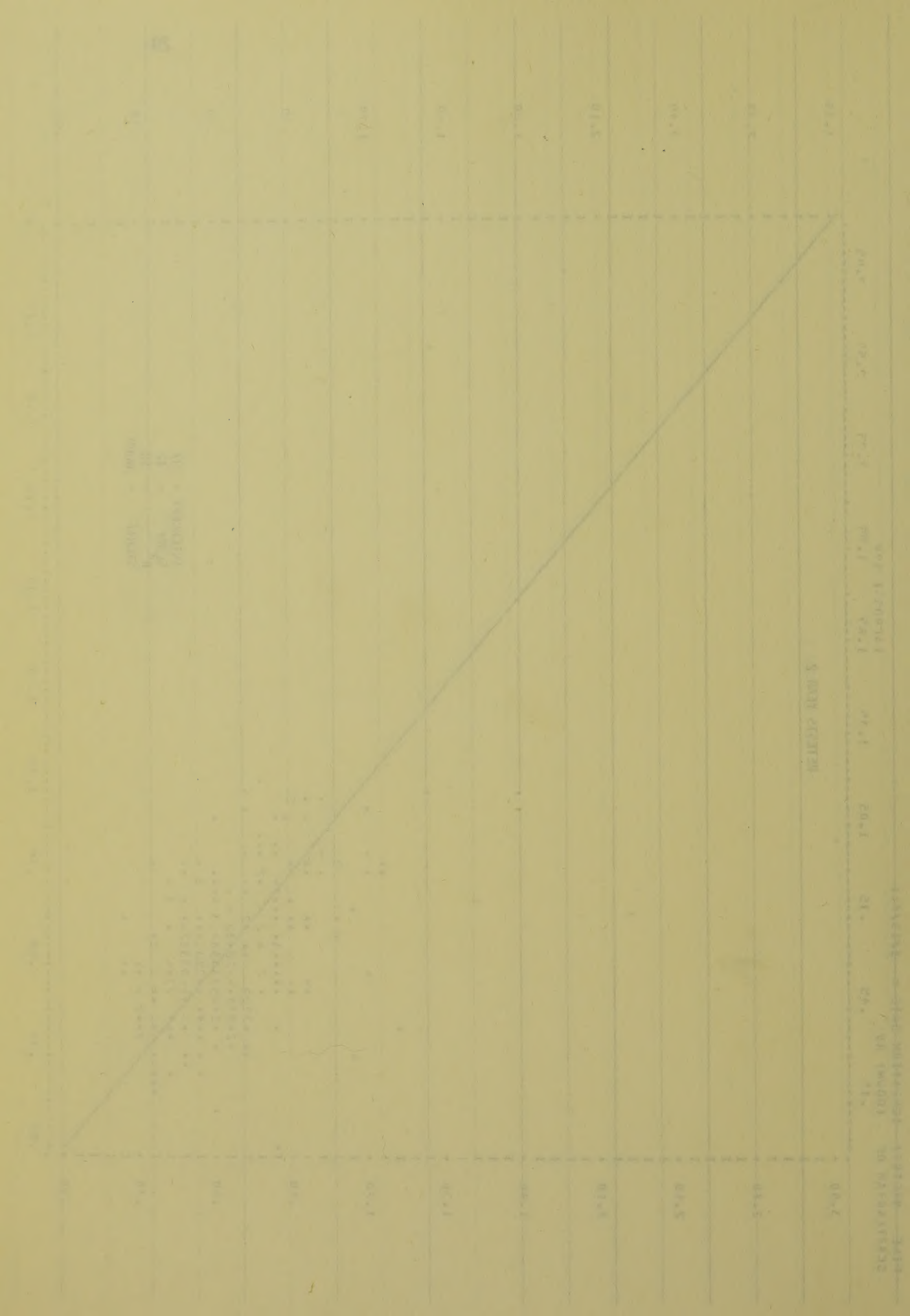




FILE N?ETST? (CREATION DATE = 3/13/91)

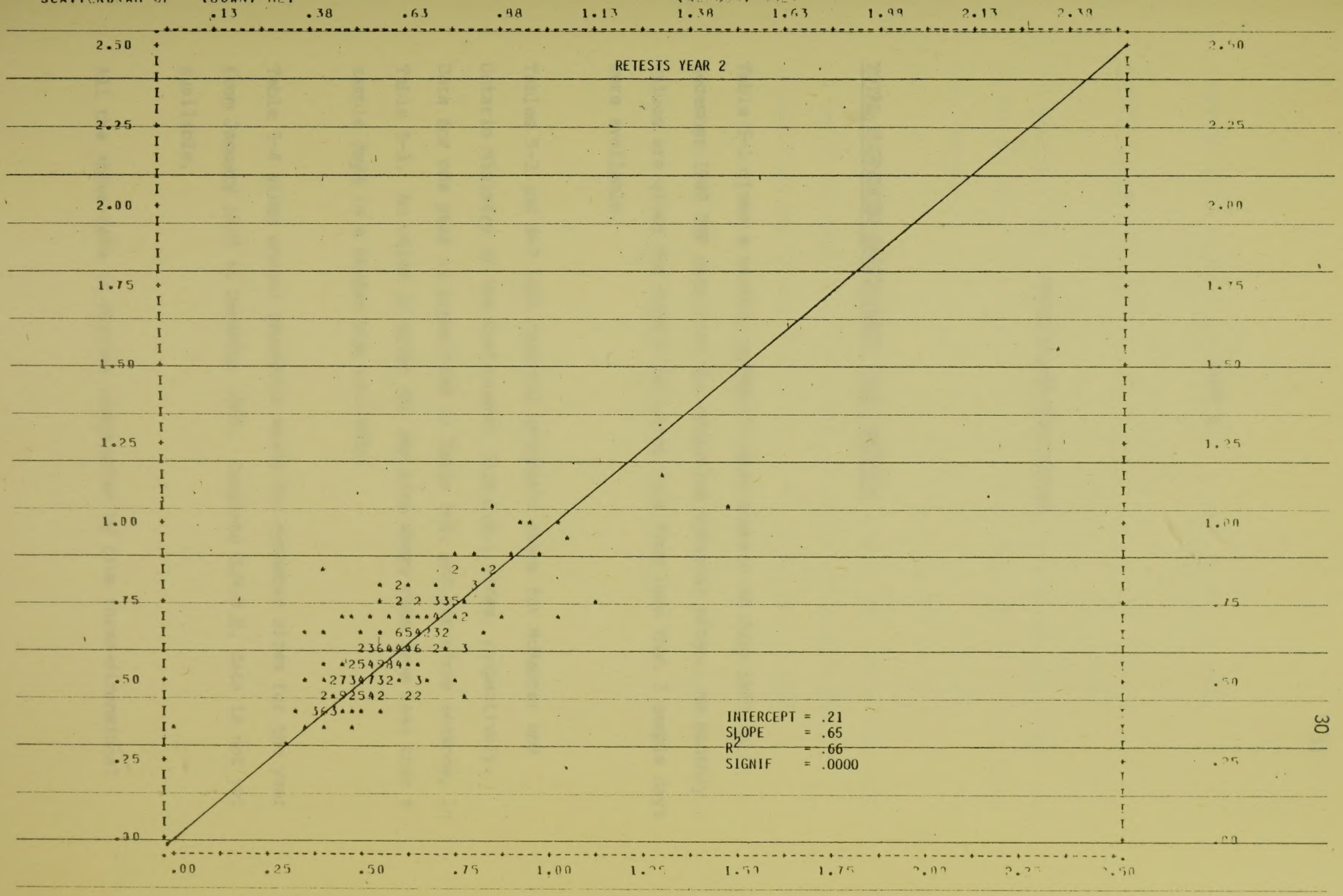
SCATTERGRAM OF (DOWN) RV (ACROSS) RV

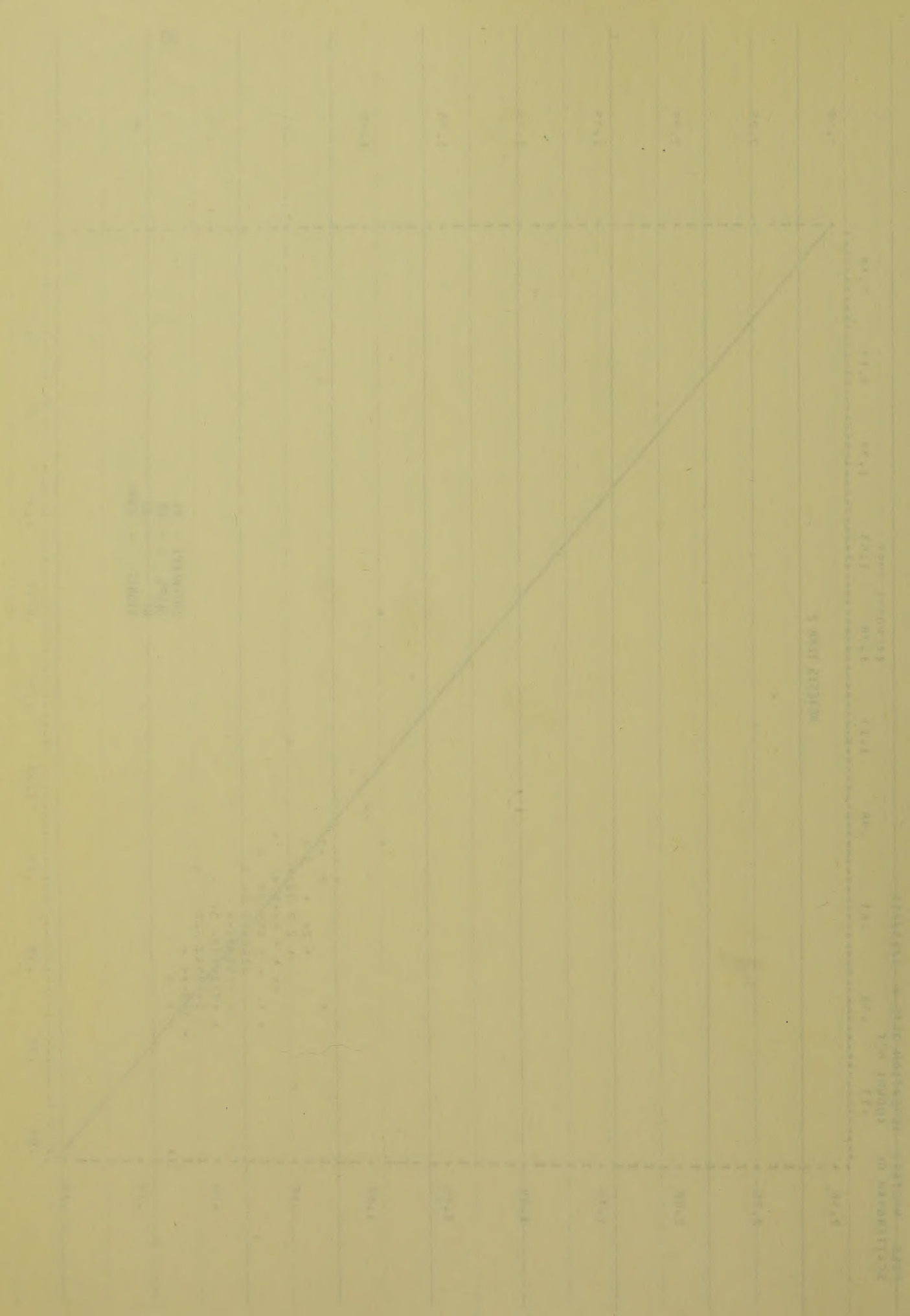




FILE N*RETST7 (CREATION DATE = 3/13/81)

SCATTERGRAM OF (DOWN) MET (ACROSS) 2MET





PART 5

PARTICULATE MONITORING

5.1 TOTAL SUSPENDED PARTICULATE (TSP) NETWORK

Table 5-1 gives a monthly geometric mean summary of July 1980 to December 1980 TSP data from the operating McMaster sites. No monthly values are given for months for which data from less than 3 sample days were available.

Tables 5-2 and 5-3 list seasonal geometric means for McMaster and Ontario Ministry of the Environment (O.M.O.E.) sites, respectively. Data for one year is summarized in Table 5-2, and for three seasons, in Table 5-3. No value is given for any site where data from less than 8 sample days in a season are available.

Table 5-4 gives annual geometric means for McMaster sites for the year from January 1980 to December 1980. Complete O.M.O.E. data is not yet available.

All the above data is further represented by five three-dimensional

response surface plots, found in Part 8 (Figures 8-1 to 8-5).

5.2 PARTICLE SIZE DISTRIBUTION (PSD) NETWORK

PSD data has been collected on our expanded network of nine sites. Due to the volume of this data, it has not been included, but is available upon request.

Since Report No. 4, we have set up two new PSD sites. These are located at two of our upper city TSP sites, San Diego and Upper Ottawa. Installation was carried out at both sites on December 5,1980. Additionally, two PSD instruments were added to the single McMaster instrument at the MOE's Barton and Sanford site in conjunction with our Indoor/Outdoor Air Quality program.

TABLE 5-1

TOTAL SUSPENDED PARTICULATE DATA

MONTHLY GEOMETRIC MEANS

JULY - DEC. 1980

McMASTER SITES

(MICROGRAMS PER CUBIC METRE)

	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Alberton	58	42	34	17	17	41
Mount Hope	58	52	N/A	19	18	44
San Diego	N/A	38	32	20	20	40
Upper Ottawa	49	39	36	18	N/A	41
Aberdeen	59	43	42	26	26	45
McElroy II	54	50	43	23	24	54
Whitney I/II	55	56	N/A	25	N/A	52
Red Hill Creek	57	42	31	19	29	41
Highview	65	49	49	20	24	53
Upper Wentworth	60	47	N/A	25	30	N/A
Cathedral Girls'	81	57	64	34	34	67
Westmount	45	40	38	19	21	42
Bishopsgate	80	77	55	30	26	64
Dundurn Castle	62	51	37	29	27	54
M.O.E.	66	68	48	42	47	70
Woodward	75	84	51	36	49	68

N/A = NOT AVAILABLE

TABLE 5-2

TOTAL SUSPENDED PARTICULATE DATA

SEASONAL GEOMETRIC MEANS

McMASTER SITES

JANUARY 1980 - DECEMBER 1980

(MICROGRAMS PER CUBIC METRE)

	JAN - MAR 1980	APR - JUN 1980	JULY - SEPT 1980	OCT - DEC 1980
Alberton	44	48	45	22
Mount Hope	45	45	53	23
San Diego	43	39	37	26
Upper Ottawa	40	38	41	28
Aberdeen	54	52	47	31
McElroy II	49	46	49	31
Whitney	56	45	53	35
Red Hill Creek	42	43	42	28
Highview	48	48	52	29
Upper Wentworth	53	54	54	32
Cathedral Girls'	70	77	66	41
Westmount	45	38	41	25
Bishopsgate	44	51	72	34
Dundurn Castle	48	45	50	34
M.O.E.	66	64	59	52
Woodward	62	82	71	51

TABLE 5-3

TOTAL SUSPENDED PARTICULATE DATA

SEASONAL GEOMETRIC MEANS

O.M.O.E. SITES

JANUARY 1980 - SEPTEMBER 1980

(MICROGRAMS PER CUBIC METRE)

	JAN - MAR 1980	APR - JUN 1980	JULY - SEPT 1980
Hughson/Hunter	74	86	71
City Hall	60	74	63
North Park	100	90	90
Kenilworth	101	77	59
Burlington/Leeds	142	146	114
Burlington/Wellington	78	83	76
Chatham/Frid	84	102	89
Barton/Sanford	90	113	99
Hughson Street North	81	65	72
Mountain Police Station	66	61	66
Cumberland Avenue	65	80	69
Barton/Nash	NIS	86	74
Westdale Library	NIS	NIS	74

NIS = NOT IN SERVICE

(Oct - Dec 1980 NOT YET AVAILABLE)

TABLE 5-4

TOTAL SUSPENDED PARTICULATE DATA
ALL SITES
ANNUAL GEOMETRIC MEANS (A.G.M.)
JANUARY 1980 - DECEMBER 1980
(MICROGRAMS PER CUBIC METRE)

QUADRANT SITE NAME & NUMBER	McMASTER (Mc) O.M.O.E. (MOE) SITE	A.G.M. ($\mu g/m^3$)
West Mountain		
San Diego (103)	Mc	35
Westmount (114)	Mc	36
McElroy II (113)	Mc	43
Mountain Police Station (310/29085)	MOE	N/A
Upper Wentworth (111)	Mc	47
East Mountain		
Bishopsgate (115)	Mc	49
Highview (110)	Mc	43
Upper Ottawa (104)	Mc	36
West Lower City		
Whitney I (108)	Mc	~~47~~ 44
Westdale Library (313/29090)		N/A
Chatham/Frid (307/29017)	MOE	N/A
Dundurn Castle (116)	Mc	44
Aberdeen (106)	Mc	45
City Hall (302/29007)	MOE	N/A
Hughson/Hunter (301/29001)	MOE	N/A
Hughson Street North (390/29067)	MOE	N/A
Burlington/Wellington (306/29012)	MOE	N/A
Cathedral Girls' (112)	Mc	62
East Lower City		
Barton/Sanford (306/29025)	MOE	N/A
Cumberland Avenue (311/29087)	MOE	N/A
Burlington/Leeds (305/29011)	MOE	N/A
Kenilworth North (304/29009)	MOE	N/A
Red Hill Creek (109)	Mc	39
Woodward (118)	Mc	66
Barton/Nash (312/29089)		N/A
M.O.E. (117)	Mc	60
North Park (303/29008)	MOE	N/A
Rural Mountain		
Alberton (101)	Mc	37
Mount Hope (102)	Mc	40

N/A = NOT AVAILABLE (yet)

PART 6

SULPHUR DIOXIDE (AND OTHER GASES) MONITORING

6.1 SAMPLING NETWORK INSTRUMENTATION AND SCHEDULING

We are continuing data collection at the 16 "base" sites distributed throughout the city as described in Report No. 3. We have been loaned several redundant Beckman* SO_2 analyzers by the Hamilton area office of the Ministry of the Environment (OME), and after some repair work were able to place two of these in working order. These now provide us with back-up units for our eight original instruments, and combined with the increased use of the LAS instruments in the field, have led to improved data collection, with reduced data loss due to instrument failure.

As described in previous reports, the SO_2 data is punched onto computer cards and combined with relevant meteorological information. We are presently analyzing this data in some detail to produce response surfaces for the city with regard to SO_2 concentration as a function of season, wind direction, etc. Results of this analysis will be presented in the next report.

Effective April 1, 1981, the technician responsible for the development and implementation of the LAS instruments is resigning to take up an industrial post. We have been fortunate enough to find a competent replacement who will start on June 1, but this will slightly delay the implementation of the final LAS instruments.

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* Beckman 906 SO_2 Analyzers.

6.2 Calibration of SO_2 Analyzers

In addition to the optical techniques described in Report No. 4, we have obtained a tank of 100 ppm SO_2 in N_2 from AIRCO. This gas was measured using the laboratory LAS as 106 + 3 ppm, and is used with a calibrated flowmeter system to provide additional dilute concentrations in the 10-250 ppb range for instrument calibration. The results using the flowmeter system agree within a few percent with our previous results using optical calibration of low concentration AIRCO mixtures. However, the flowmeter system delivers a large volume of calibrated gas, and will be very useful in calibrating the indoor-outdoor monitors.

As a final check on our SO_2 calibration procedures, a stable tank of low concentration SO_2 in air was carefully measured on our LAS instruments. The measured concentration was 163 + 5 ppb SO_2. This tank was then taken to Toronto and measured by the Instrumental Unit of the Air Quality and Meteorology Section, Air Resources Branch, OME. They used the NBS calibrated permeation tube, which is the basis for all the OME calibrations. The OME value was 162.8 ppb. The excellent agreement of these two measurements confirms our confidence in the optical techniques used to calibrate our SO_2 network.

6.3 PRESENTATIONS

A paper entitled "Very High Sensitivity Spectroscopy Using Tunable Diode

Lasers" was presented at a poster session during the Topical Meeting on Spectroscopy in Support of Atmospheric Measurements, sponsored by the Optical Society of America. This meeting was held November 10-12, 1980 in Sarasota, Florida. This paper is included as Appendix 6-1.

PART 7

INDOOR SAMPLING

7.1 INTRODUCTION

A protocol for a program of indoor air quality monitoring, both in schools and in residences was included in Current Report No. 4, October 1, 1980. The program will involve seasonal sampling, both indoors and immediately outdoors, for particulates, sulphur dioxide, and nitrogen dioxide in 24 Hamilton residences and 16 Hamilton Public Elementary schools. It will enable us to estimate exposures of our population of interest (school children) during the major portion of the day that they spend indoors.

Sufficient funds for start-up of the indoor-outdoor sampling program were made available effective December 18, 1980. The 21-month project schedule has been modified accordingly, as shown in Figure 7-1. All operational and partial equipment funding was provided by The Environmental Toxicology Division of the Environmental Health Directorate, Health and Welfare Canada. Additional funds for equipment are to be provided by the World Health Organization.

7.2 PILOT STUDY

A field survey was conducted in June and July 1980 to assess the logistics involved in indoor-outdoor sampling. A small number of samples were collected in Hamilton, Ontario. The sites included a school, a residence and the Ontario Ministry of the Environment (O.M.O.E.) Air Monitoring Station at North Park. Personal samplers, built by the Gage Research Institute, were used for all sampling with modifications to allow operation using line voltage. Analysis of samples was performed by Gage Institute staff.

Results of the pilot project were inconclusive. However, the limitations of the Personal Sampler when used as an in situ instrument, as opposed to its intended use as a personal sampler, were identified. It was found that the absorbing solutions evaporated when sampling duration exceeded ten hours, that no effective on-off programmable function was available, and that flow rates were not sufficiently stable over 24 hours. In order to extend sampling duration to allow comparisons with High Volume particulate sampling, a new sampler was developed which was capable of 24 hour sampling. It incorporates a programmable start-stop timer, an elapsed time recorder and an electronics package to provide a constant flow rate.

Data collected during the pilot study sampling program are presented in Tables 7-1 to 7-3.

7.3 PERSONNEL

Since Report No. 4 (September, 1980) was released four additional technicians have joined our staff to provide a full complement as funded. These people were hired on gradually, to allow for extensive training by experienced staff and to carry out duties as funding became available. All new staff are now well acquainted with servicing the high-volume particulate sampling network and the analytical and quality assurance procedures involved. Total staff involved in air sampling duties now stands at five technicians and one supervisor. These people are currently preparing and assembling indoor-outdoor sampling equipment and servicing and analyzing the ambient high-volume network. When all samplers are operational, four technicians will service the sampling networks while the fifth person will be responsible for the preparation and analysis of the sampling solutions in the laboratory.

7.4 MULTIPOLLUTANT SAMPLER

7.4.1 Sampler Design

The recently developed McMaster multi-pollutant sampler retains the basic princples found in the personal sampler used in the pilot study. The instrument is capable of sampling for sulphur and nitrogen dioxides at levels as low as a few parts per billion in ambient air (according to

the literature). The sampler incorporates larger amounts of chemical absorbing solutions, line voltage power supply, constant motor speed control, programmable on-off operation and other features designed to meet specific project requirements.

The sample train is illustrated diagrammatically in Figure 7-2. In essence, it consists of an inverted teflon filter for particulate sample collection; this also protects the sampling train from particulate contamination. Downstream of the filter the sample air stream is split into two equal parts. These two sample streams pass through separate flowmeters, allowing a visual check of flow rates. Needle valves on each line permit balancing of the two flow rates. The air streams then bubble through separate fritted impingers containing SO_2 and NO_2 absorbing solutions. The two air streams are combined at the moisture trap, provided to protect the pump from solution overflow, which could produce unstable flows. The pump, a Brailsford Model 1A, is fitted with a custom electronic motor speed controller which continually compares motor speed to a selected oscillator frequency. Finally the air stream is passed through a noise muffler before being exhausted to the ambient air.

The samplers are designed and constructed in modular form which speeds construction, eases sample collection and enables major repairs to be carried out in field locations. The modules are as follows:

1. Filter cassette with teflon filter;

2. Air-stream bisector and flow meter structure;

3. Needle valve assembly;

4. Sample cartridge, consisting of aluminum box, impingers and moisture trap;

5. Pump and speed controller;

6. Programmable and elapsed timers, relay and other electric components;

7. Instrument enclosure with muffler (indoor enclosure is a simple plastic case while the outdoor enclosure is a temperature-controlled insulated case);

8. Weather resistant shelter (outdoor only).

All sample lines upstream of the impingers are of stainless steel, teflon or glass construction.

7.4.2 Sampler Construction

Two operational sampling units are now available for evaluation and calibration. A variety of tests and calibrations have been completed with satisfactory results. Most tools and equipment required to form

and machine components and assemble instruments have been acquired. Modular components have been assembled. Work is continuing on the modules while the electrical components and final sampler assembly are being completed for units in more advanced stages of production.

The first five indoor instruments are expected to be operating at field sites by mid April. We hope to have the remaining 18 instruments in the field by the end of April.

7.5 VALIDATION AND CALIBRATION

The multi-pollutant samplers will be validated for SO_2 and and NO_2 using dynamic environmental chamber methods. One sampler will initially be held back from field duty for validation purposes. The unit will also be used as a spare to reduce sampler down-time.

All flowmeters used in the instruments have been individually calibrated using the standard wet-bubble meter method. Flow calibrations in the field will be performed at regular intervals throughout the survey period. Preliminary results based on evaluation of a prototype sampler indicate that the motor controller provides excellent long term (continuous 72-hour operation) flow stability with flows varying less than 0.1% from set-up rate. Field tests of temperature controlled outdoor enclosures indicate good temperature stability over ambient temperatures ranging from -30° to $+30^{\circ}C$. A switchover curcuit must be incorporated to automatically switch from heating to cooling modes of

operation. Design of this circuit is nearly complete. Further evaluation is required but modifications to each unit are expected to be completed before the field survey begins.

Continuous field validation of SO_2, NO_2 and particulates will take place over the duration of the project. The validation site is the O.M.O.E. Barton and Sanford Air Quality Monitoring Station. The Ministry of the Environment continually monitors levels of SO_2, NO_2 and particulates at this site. We have completed the installation of two additional (for a total of three) high volume Particle Size Distribution samplers (Anderson Cascade Impactors). Three multi-pollutant samplers will be installed as soon as they become available. The M.O.E. data will be used as a secondary standard for field validation of our multi-pollutant samplers.

7.6 ANALYTICAL EQUIPMENT AND SUPPLIES

Sufficient equipment and supplies have been located or received to enable us to begin analysis coinciding with sampler availability.

Some delays have been experienced due to reorganization of laboratory facilities. More working space has been made available. Wet lab facilities and support equipment have been set up. Trial runs of sample preparation and analysis have been performed and standard curves have been drawn; we now feel that all aspects of chemical analysis are satisfactory. Sampling solutions and particulate filters are prepared

and ready for full survey operation.

7.7 QUALITY CONTROL

7.7.1 Sampling

As mentioned previously, the sampling instrument has been designed to ensure a constant flow during sampling periods. Absorbing solutions will be protected from outdoor temperature extremes through the use of temperature-controlled enclosures. All sample line materials are of non-reactive materials and will be thoroughly cleaned before final assembly to ensure the sample train is free of contaminants. Sample quality will be ensured by the use of sample cartridges which will eliminate the handling of chemical solutions in the field.

7.7.2 Analysis

United States Environmental Protection Agency recommended analytical methods, are being used with strict adherence to methodology. As monitoring gets underway, sample solutions will be divided and analyzed twice, in order to verify laboratory procedures. Later on, this duplication will be limited to a small portion of the samples collected, sufficient to monitor long-term analytical techniques.

Gravimetric particulate analysis will be performed using the Cahn 25

Automatic Electrobalance. All filters will be treated in a dessicator prior to weighing. Initially, each filter will be weighed twice to ensure accurate readings. Duplication of weighings will be reassessed later, based on the accuracy of results and the man-hours required to maintain this procedure. Long-term balance stability will be monitored by weighing a single standard weight prior to each weighing session.

Raw data generated will be immediately recorded on coding forms to reduce risk of transcription errors and time required to store and analyze results.

7.8 TRANSPORTATION OF EQUIPMENT AND PERSONNEL

Three new Ford Fairmont station wagons have been leased and received. They will provide adequate transportation for setting up and servicing full network operation for the duration of the project.

7.9 SITE SELECTION

Site selection is underway in accordance with protocols outlined in Current Report No. 4.

7.9.1 School Network

All elementary schools used in the Pulmonary Function Study have been

photographed. In addition, a Commercial/Institutional Building Characteristics description form has been completed for each school. Based on this information four schools have been chosen from each of the quadrants of the city. The school year sampling at each school will take place on a two week rotation. A sample will be taken every two days. The indoor-outdoor samplers will be moved to another school in the quadrant at the end of the two-week rotation period and the cycle will continue.

7.9.2 Residential Network

Selection of residential sites is almost complete. Bulletins placed in busy public places around the City of Hamilton met with positive responses. The complete network will require a total of 24 sample residences spread across six sectors of the city. To date we have received completed Residential Description Forms from approximately 60 households. These replies will be studied to determine their suitability, based on protocols outlined in Report No. 4. Based on past experience, we do not expect any problems in obtaining sufficient suitable residences to the number required.

7.10 METEOROLOGICAL DATA

Complete records of meteorological data are available at three stations in the Hamilton area. A system of collecting, recording and analyzing this data will be set up. In the future this system will be utilized to

maintain meteorological data concurrent with air quality data.

7.11 SUMMARY OF PROGRESS

There has been approximately a one-month delay in field program commencement, the main contributing factor being slow supplier delivery of instrument parts. During this time modules were built up as parts and materials became available. Sampling and analytical techniques have been thoroughly tested. New staff have had adequate time to become well acquainted with project objectives. The initial delay in field operations has had beneficial side-effects: it has been possible to carry out detailed planning and preparations, which will result in higher quality samples and analyses from the onset of field sampling.

Table 7-1

SCHOOL DATA

(Pilot Study)
(HIGHVIEW SCHOOL)

DATE 1980	LOCATION (Instr.#)	SO_2 (ppm)	NO_2 (ppm)	HI - VOL PARTICULATES ($\mu g/m^3$)	HI - VOL T.S.P. ($\mu g/m^3$)	HI - VOL TOTAL P.S.D. ($\mu g/m^3$)
June 23 1000 - 1600 HRS.	CLASSROOM #10 (#3)	0.0008	0.012	N/A	88.4	158.1
	STAFFROOM (#4)	0.0014	0.026	187		
	OUTSIDE (#7)	0.001	0.051	399		
June 24-25 900 - 900 HRS.	CLASS #10 (#3)	0.002	0.022	N/A	126.6	158.3
	STAFFROOM (#4)	0.001	0.035	2659		
	OUTSIDE (#7)	0.003	0.022	163		
June 25-26 1700 - 800 HRS.	CLASS #10 (#3)	0.001	0.052	165	98.1	153.5
	STAFFROOM (#4)	0.0009	0.031	178		
	OUTSIDE (#7)	0.0046	0.017	163		

TABLE 7-2

RESIDENCE DATA

(PILOT STUDY)

(1221 Main St. West, Hamilton)

DATE (1980)	LOCATION (INST. NO.)	LO-VOL PERSONAL		
		SO_2 (ppm)	NO_2 (ppm)	PARTICULATES ($\mu g/m^3$)
July 3 0000 - 800 HRS.	LIVING ROOM (#4)	0.001	0.042	267
	LIVING ROOM (#7)	0.001	0.029	85
July 4 1000 - 1700 HRS.	LIVING ROOM (#7)	0.0036	0.042	N/A
	LIVING ROOM (#4)	0.0056	0.037	217
	OUTSIDE (#3)	0.014	0.058	327
July 6 100 - 1300 HRS.	LIVING ROOM (#4)	N/A	0.028	10
	BEDROOM (#7)	0	0.042	N/A
	OUTSIDE (#3)	0.0017	0.018	N/A
July 10 0000 - 800 HRS.	LIVING ROOM (#4)	0.0029	0.024	244
	OUTSIDE (#3)	0.026	0.076	263
July 11 800 - 1700 HRS.	LIVING ROOM (#4)	0.011	0.027	315
	OUTSIDE (#3)	0.0016	0.017	269

TABLE 7-3

COMPARISON OF SAMPLER PERFORMANCE
VS. O.M.E. SECONDARY STANDARDS
(SITE: NORTH PARK AIR MONITORING STATION)
(PILOT STUDY)

≈ 8 HR. SAMPLES

DATE (1980)	INSTR. NO.	SO_2			NO_2		
		O.M.E. (ppm)	MULTI (ppm)	EFFICIENCY % $\left(\frac{\text{MULTI}}{\text{O.M.E.}}\right)$	O.M.E. (ppm)	MULTI (ppm)	% $\left(\frac{\text{MULTI}}{\text{O.M.E.}}\right)$
June 13-14 2100 - 500 HRS.	3	0.036	0.028	77.8	0.083	0.06	72.3
	4	0.036	0.020	55.5	0.083	0.057	68.7
June 14 1430 - 2200 HRS.	3	0.027	0.022	81.5	N/A	0.041	N/A
	4	0.027	0.017	63.0	N/A	0.047	N/A
June 15 100 - 900 HRS.	3	0.024	0.024	100	0.05	0.039	78.0
	4	0.024	0.014	58.3	0.05	0.042	40.0
June 15 1600 - 2400 HRS.	3	0.01	0.0015	15.0	0.01	0.014	140.0
	4	0.01	0.0017	17.0	0.01	0.020	200.0

FIGURE 7-1

REVISED SCHEDULE

	June	Pilot Field Study
1980	September	
	October	
	November	
	December	Funding Effective December 18
1981	January	- hiring staff
	February	- arranging for transportation
		- setting up lab
		- construct prototype of samplers
		- order sampling equipment and parts
		- order analytical equipment and supplies
		- validation of sampling system
	March	- "Spring" sampling begins
		END OF FISCAL YEAR
	April	
	May	End of "spring" sampling season
	June	School system "summer" sampling
	July	Residential system "summer" sampling
	August	Residential system "summer" sampling
	September	"Fall" season sampling begins
	October	
	November	End of "fall" sampling season
	December	"Winter" sampling season begins
1982	January	
	February	Sampling program ends
	March	"Clean-up" sampling network
		Lab analysis completed
		Field work ended
		Data Analysis begins
		END OF FISCAL YEAR
	April	
	May	
	June	Report preparation begins
	July	
	August	Report presentation
		END OF FISCAL PERIOD

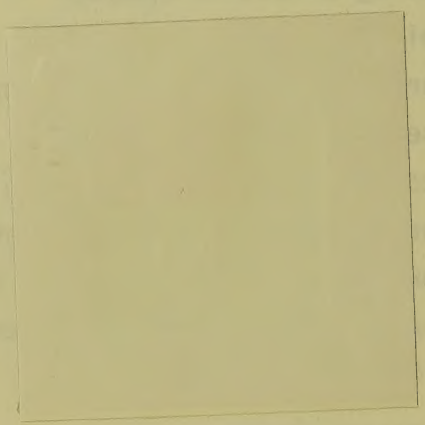
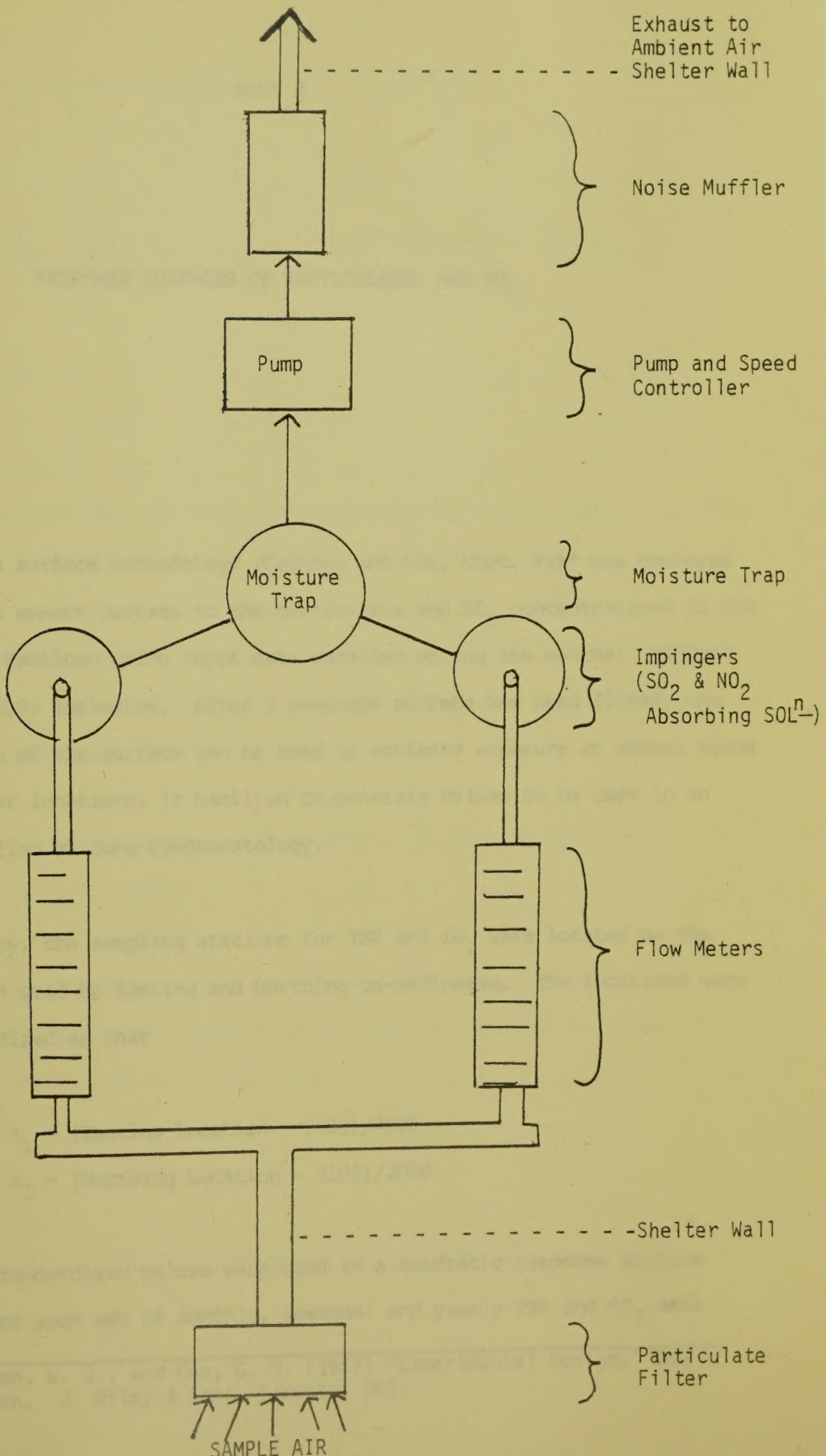
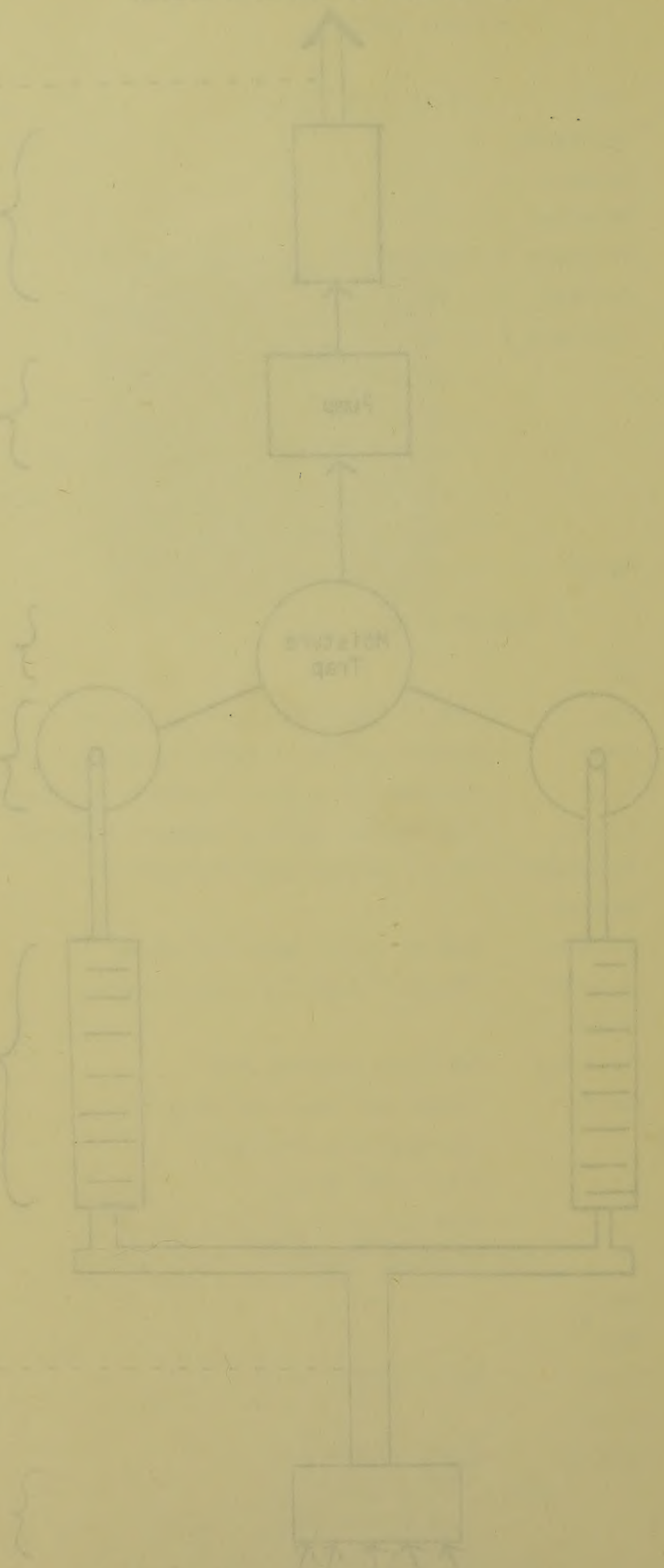


FIGURE 7-2
FLOW DIAGRAM OF SAMPLING SYSTEM





PART 8

RESPONSE SURFACES OF PARTICULATES AND SO_2

8.1 METHOD

Response surface methodology (Cochran and Cox, Chpt. 8A)* was employed to fit a smooth surface to the particulate and SO_2 concentrations in the city of Hamilton using input data obtained during the months: 1979:07 to 1980:10, inclusive. After a response surface has been fitted, the equation of the surface can be used to estimate exposure at school sites (or other locations) in Hamilton to generate values to be used in an explanation of lung symptomatology.

Explicity, the sampling stations for TSP and SO_2 were located on the Hamilton grid by Easting and Northing co-ordinates. The locations were standardized so that

$$X_1 = (\text{Easting Location} - 2600)/4000$$
$$X_2 = (\text{Northing Location} - 2100)/2000$$

These standardized values were used in a quadratic response surface model for each set of monthly, seasonal and yearly TSP and SO_2 data.

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* Cochran, W. G., and Cox, G. M. (1957) "Experimental Designs" 2nd Edition. J. Wiley & Sons, Toronto, ONT.

For each of these responses, a model of the form

$$y = \beta_0 + \beta_1 X_1 + \beta_{11} X_1^2 + \beta_2 X_2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon$$

was fitted.

Once the model was fitted to each response, the fitted equation was used to plot the response surface in a three-dimensional plot.

For consistency with air quality reporting procedures, the arithmetic mean was used for the same time periods when dealing with SO_2 data. (See Current Report No. 4)

The equations were then used to estimate the smoothed exposure at each school for each response.

The SPSS Regression package was used to determine the coefficients in the equations, while a special FORTAN program was written to estimate the TSP and SO_2 values at the school sites.

8.2 RESULTS

The fitted equations for each monthly set of TSP data are listed in Table 8-1.

These equations were used to plot the three-dimensional response surfaces for TSP. Figures 8-1 through 8-5 are the response surfaces for July - October 1980 and for the summer of 1980. (See Current Report No. 4 for further examples of the response surface).

Table 8-2 contains the estimated exposure to particulates at the 35 schools in the study. These results could then be linked with the epidemiological data from the home interviews and the lung function testing, in an attempt to explain any changes in the lung measurements on the children in each school. (See Current Report No. 4 for similar information on estimated SO_2 exposures.)

TABLE 8-1

RESPONSE SURFACE EQUATIONS FOR TSP

Response Time Period	Equation Coefficients						
	Const.	X_1	X_1^2	X_2	X_2^2	X_1X_2	R^2_m
1979-04	61.84	32.85	-19.87	70.32	-78.37	43.34	.54
1979-05	72.76	21.14	-5.8	74.15	-81.49	17.29	.36
1979-06	94.06	16.82	25.18	75.61	-75.61	26.73	.70
1979-07	70.09	12.32	-4.63	45.26	-14.93	38.32	.83
1979-08	69.06	10.09	-4.85	35.24	-43.53	68.19	.76
1979-09	90.7	1.5	-59.7	65.5	-77.4	102.1	.53
1979-10	46.7	20.9	-37.2	57.5	-54.1	89.3	.58
1979-11	48.70	8.16	-5.60	42.07	-23.41	49.23	.70
1979-12	44.18	8.58	-12.70	38.75	-2.53	69.21	.73
1980-01	66.65	30.76	63.93	-101.69	-37.21	68.64	.61
1980-02	68.52	42.42	64.96	-90.00	59.37	125.88	.59
1980-03	73.44	28.96	76.56	-107.39	-106.46	116.97	.58
1980-04	68.42	28.56	82.64	-184.27	-105.16	83.33	.52
1980-05	80.70	44.41	77.34	-182.88	-57.8	76.27	.53
1980-06	74.36	26.69	68.80	-74.38	-76.36	100.88	.57
1980-07	74.80	29.90	48.41	64.57	17.79	31.30	.60
1980-08	62.44	26.69	39.18	36.67	23.65	32.15	.40
1980-09	60.02	18.37	39.86	82.74	40.98	52.40	.47
1980-10	31.87	16.25	37.70	11.56	6.62	51.10	.59

Table 8-1 (Cont'd)

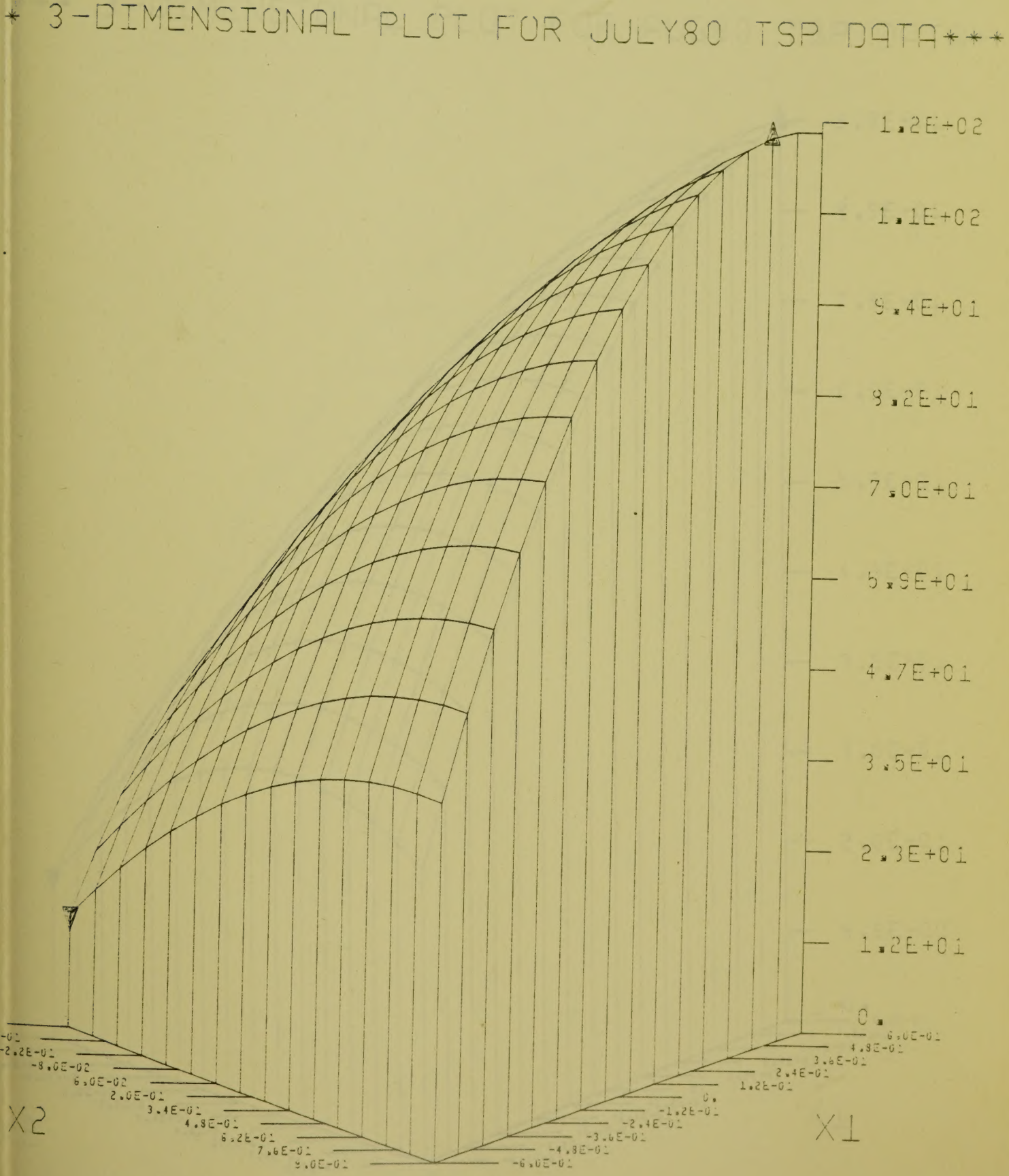
SEASONAL DATA	CONST.	X_1	X_1^2	X_2	X_2^2	$X_1 X_2$	R_m^2
Summer July-Sept. 1979	69.47	32.11	74.3	-74.80	-73.19	49.94	.55
Fall Oct.-Dec. 1979	48.36	.9	50.58	-46.22	51.62	86.38	.55
Winter Jan.-March 1980	50.65	15.95	49.21	-77.66	-35.95	97.67	.64
Spring Apr.-June 1980	64.37	24.37	60.54	-46.96	-42.08	49.98	.54
Summer July-Sept. 1980	65.77	25.24	41.42	-68.09	-27.77	45.83	.51
ANNUAL DATA							
July 79-June 80-	64.35	24.18	61.85	-34.88	-58.19	71.40	.61

TABLE 8-2

PREDICTED VALUES AT SCHOOLS

School Number	School Name	Particulates (TSP) July	Aug	Sept	Oct	Summer '80
01	Bartonville	74.22	63.40	65.88	31.71	64.0
02	Westwood	53.32	45.80	57.04	22.55	46.93
03	Prince of Wales	90.43	75.04	72.60	46.17	78.55
04	James MacDonald	42.39	36.74	50.05	18.77	37.42
05	Allenby	75.59	61.62	64.92	36.92	62.39
06	Seneca	49.07	43.10	61.70	21.76	42.76
07	West Avenue	90.81	73.41	68.10	48.17	76.69
08	Mountview	45.53	41.15	73.02	21.68	36.59
09	Lake Avenue	62.27	59.38	96.37	31.31	48.73
10	Peace Memorial	73.80	61.79	59.17	30.78	64.76
11	Strathcona	79.91	63.74	63.77	41.68	64.06
12	Eastmount Park	73.33	61.24	58.79	30.74	64.50
13	Earl Kitchener	70.32	58.12	65.34	33.11	58.42
14	Richard Beasley	53.49	43.77	37.74	17.50	44.91
15	Red Hill	56.28	48.63	54.37	18.95	44.65
16	Vern Ames	53.38	43.70	38.23	18.14	45.46
17	W. H. Ballard	82.40	70.97	77.89	40.12	71.32
18	Pauline Johnson	53.60	44.69	45.27	20.50	47.07
19	King George	90.24	75.22	73.71	46.03	78.53
20	Queensdale	71.72	59.80	61.45	31.38	62.54
21	Central	79.50	65.02	64.95	38.40	67.27
22	Fernwood Park	61.23	50.91	46.65	21.91	52.56
23	Prince Philip	48.33	42.34	73.70	23.50	35.89
24	Franklin Road	63.36	52.76	49.73	24.13	55.51
26	Sherwood Heights	67.17	56.58	54.79	25.72	57.74
27	Stinson Street	81.81	62.72	65.11	38.10	71.26
29	Wentworth Street	89.26	73.16	69.08	45.36	76.81
30	Lisgar	49.69	40.34	33.67	14.79	40.23
31	Dr. J. Edgar Davey	86.54	70.38	66.67	43.84	73.48
33	Viscount Montgomery	71.87	62.56	71.02	31.19	60.87
35	Rosedale	64.15	54.71	56.42	23.92	53.78
37	Sir Isaac Brock	57.07	52.30	74.34	22.76	44.01
53	Lloyd George	94.56	79.22	80.56	51.76	82.00
57	Robert Land	96.28	77.77	71.62	54.03	81.35
59	Gibson	92.53	75.88	71.72	48.79	79.58

FIGURE 8-1


*** 3-DIMENSIONAL PLOT FOR JULY80 TSP DATA***
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9.4E+01
8.2E+01
7.0E+01
5.9E+01
4.7E+01
3.5E+01
2.3E+01
1.2E+01
0.
X2
X1

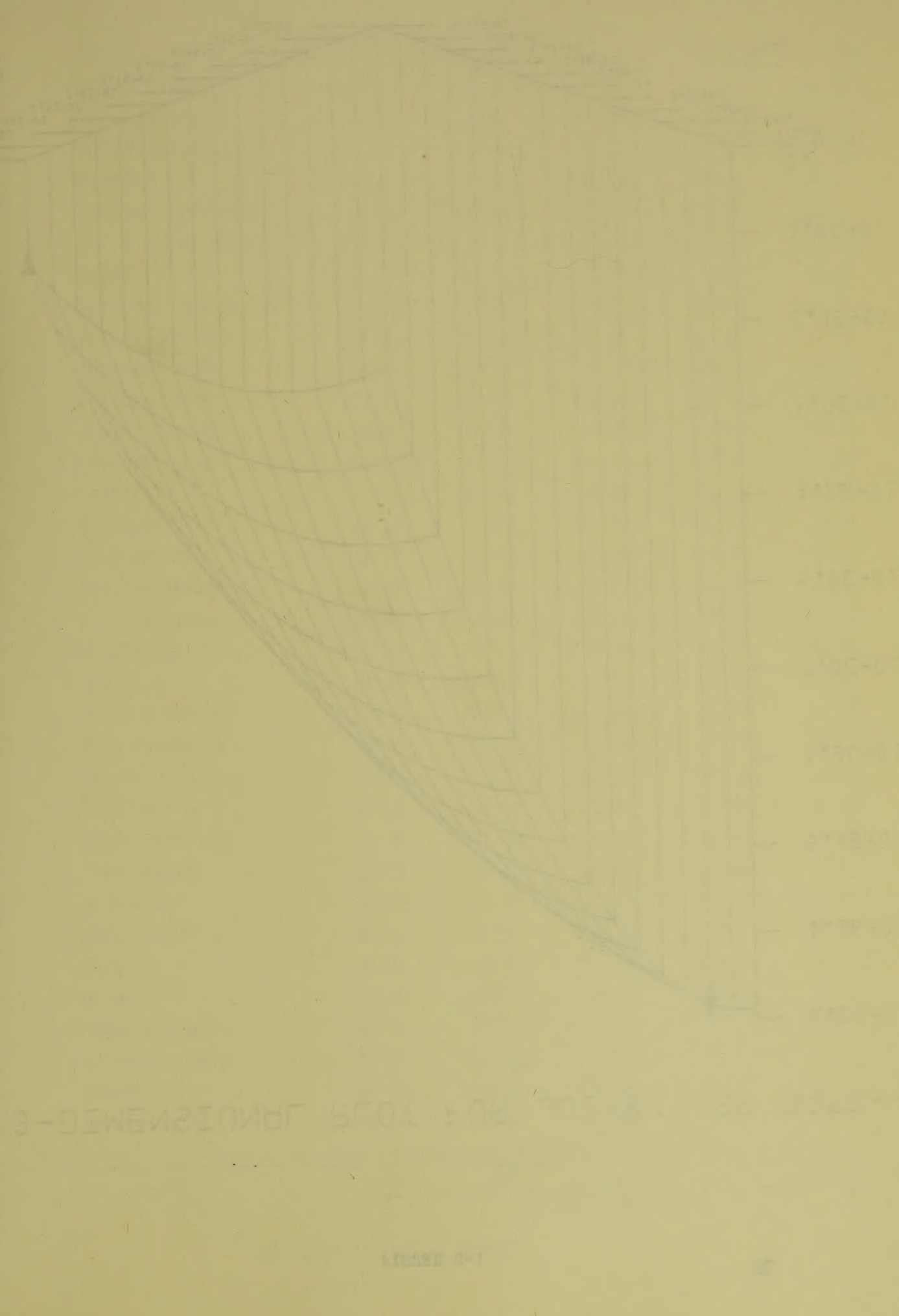
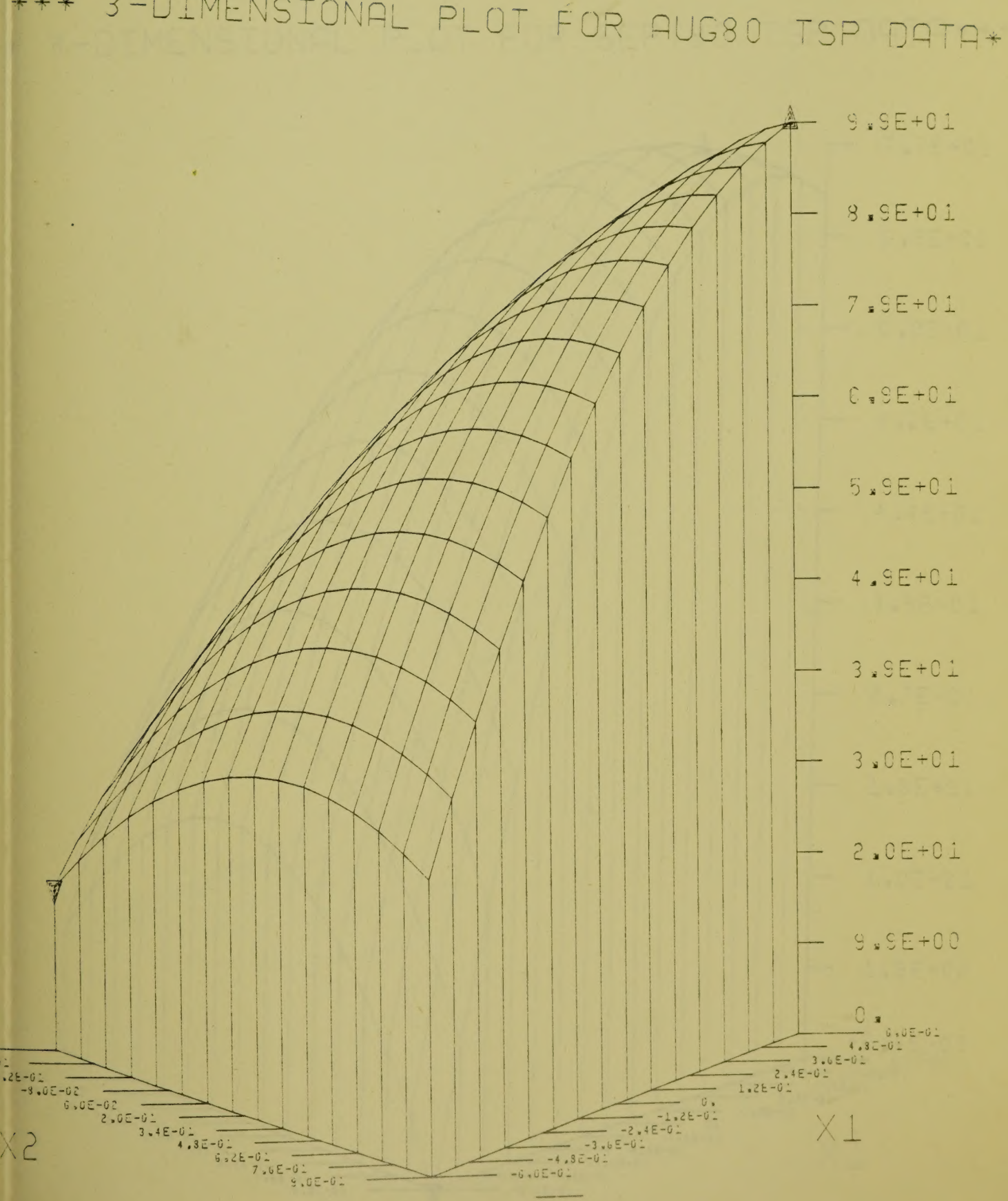


FIGURE 8-2


*** 3-DIMENSIONAL PLOT FOR AUG80 TSP DATA*
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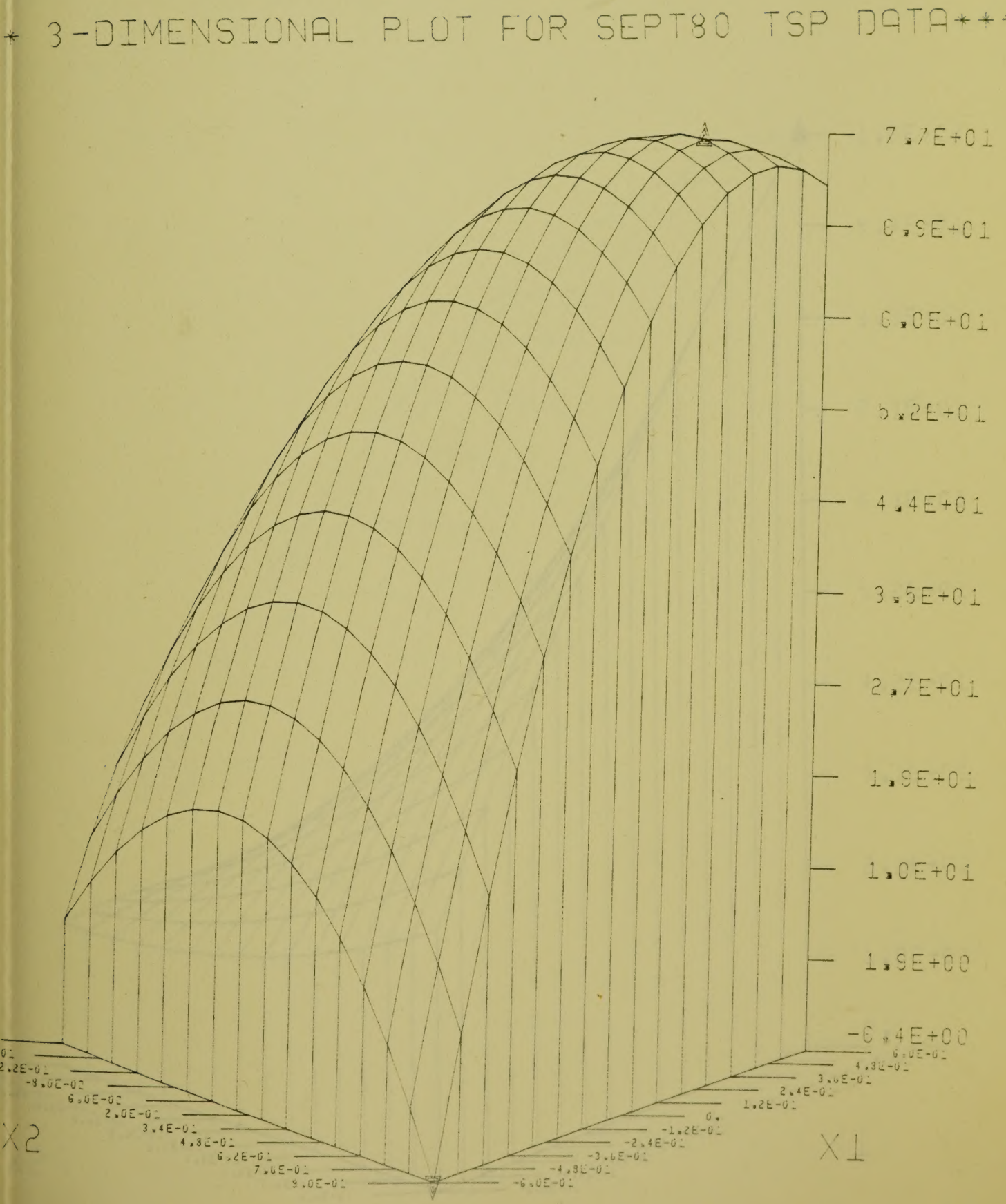
7.9E+01
6.9E+01
5.9E+01
4.9E+01
3.9E+01
3.0E+01
2.0E+01
9.9E+00
0.
X2
X1

FIGURE 8-3


* 3-DIMENSIONAL PLOT FOR SEPT80 TSP DATA***
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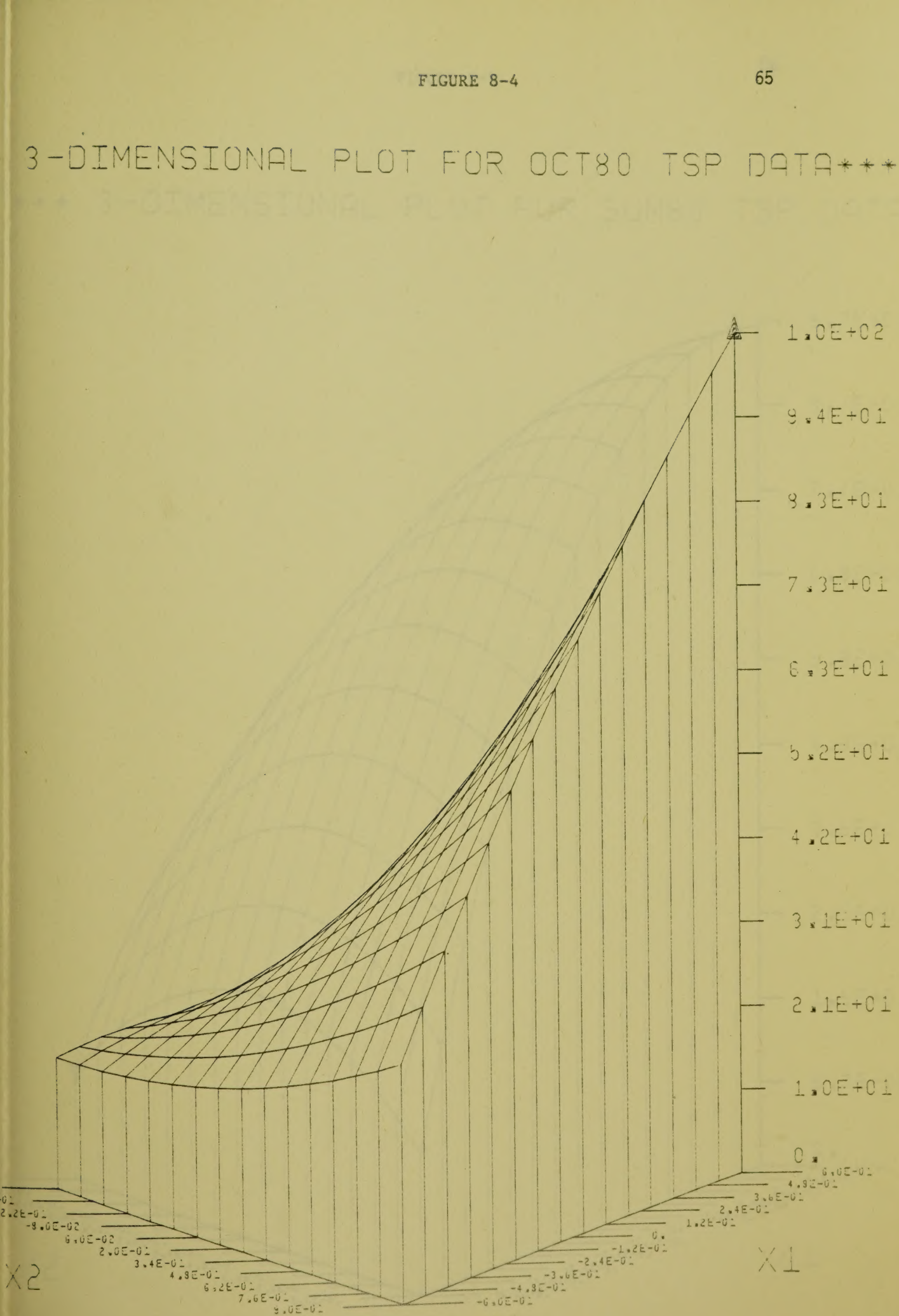
6.9E+01
6.0E+01
5.2E+01
4.4E+01
3.5E+01
2.7E+01
1.9E+01
1.0E+01
1.9E+00
-6.4E+00
X2
X1

FIGURE 8-4


3-DIMENSIONAL PLOT FOR OCT80 TSP DATA****
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7.3E+01
6.3E+01
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4.2E+01
3.1E+01
2.1E+01
1.0E+01
0.
X1
X2

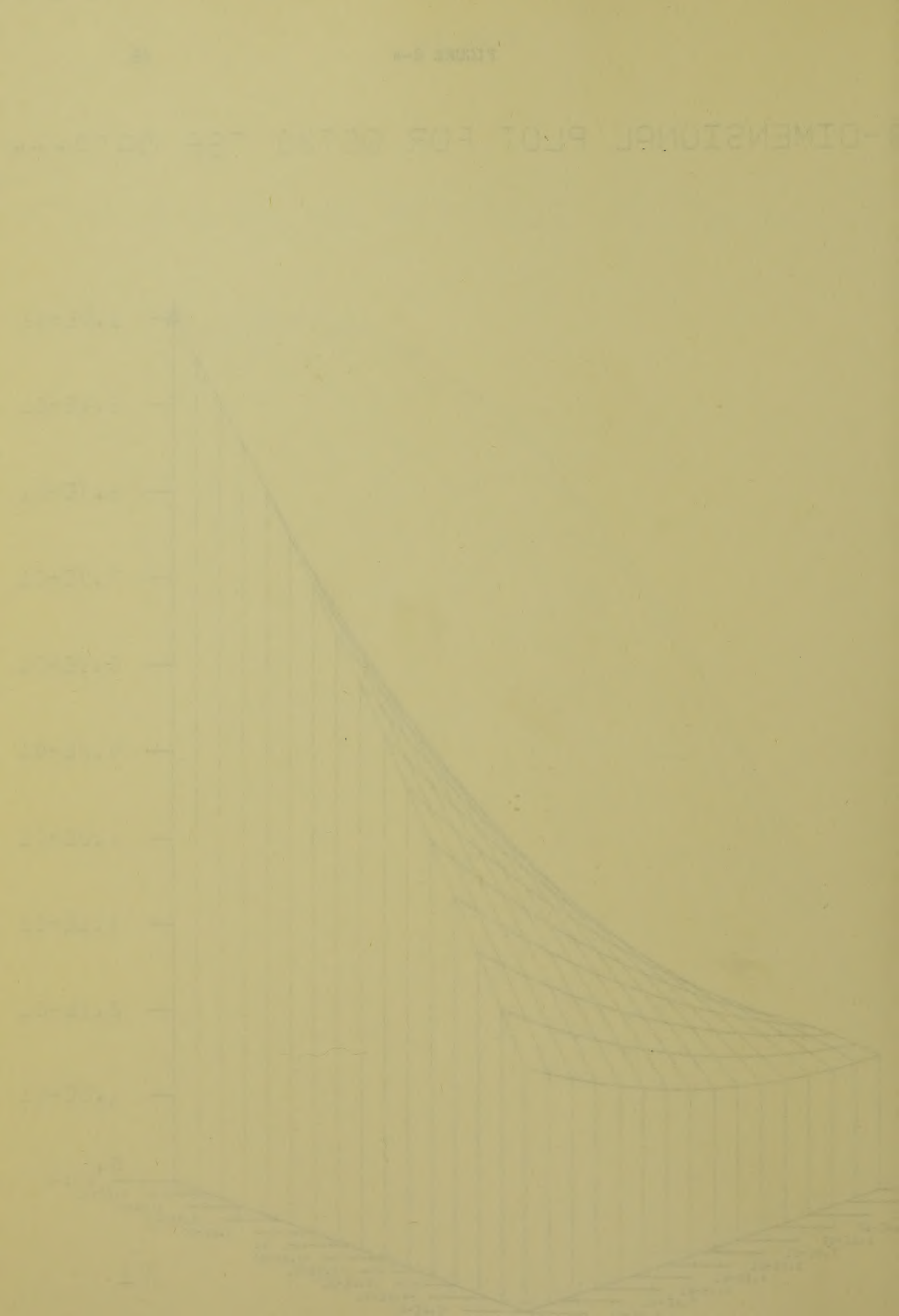
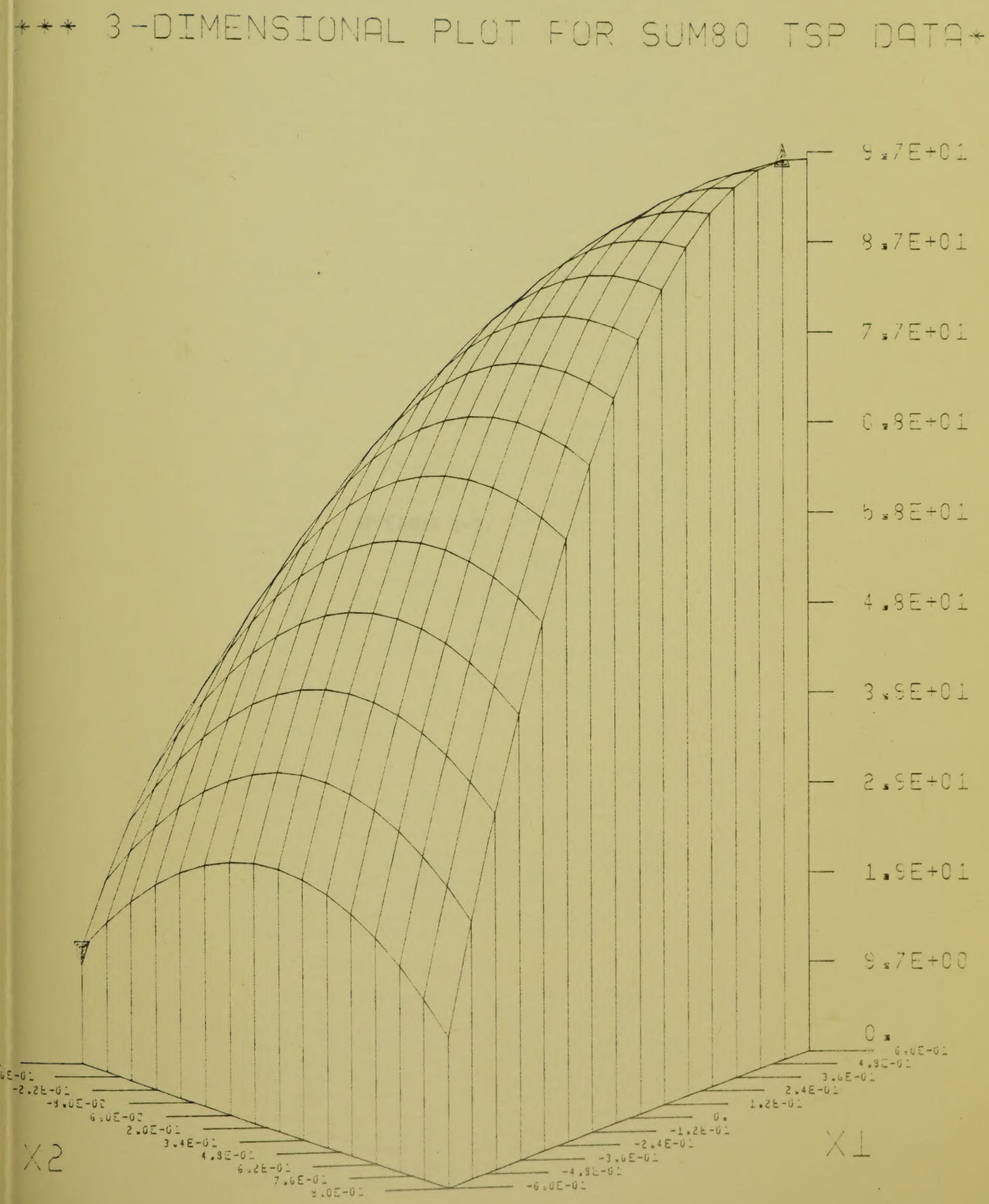


FIGURE 8-5


*** 3-DIMENSIONAL PLOT FOR SUM80 TSP DATA*
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6.8E+01
5.8E+01
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3.9E+01
2.9E+01
1.9E+01
9.7E+00
0.
X2
X1

APPENDIX 1-1

AIR QUALITY AND ITS EFFECT ON THE RESPIRATORY HEALTH OF SCHOOL CHILDREN: A STUDY IN HAMILTON, ONTARIO. 1978-1981*

B.K. Garside, C.H. Goldsmith, A.T. Kerigan, L.D. Pengelly

In the summer of 1977, a two-month pilot study in two schools in Hamilton with quite different ambient pollution levels, demonstrated the feasibility of studying the impact of air quality on the respiratory health of school children.

Study Design

Hamilton, Ontario is a city located on the south-western tip of Lake Ontario and is the primary location of the steel industry in Canada. Hamilton has a population slightly in excess of 350,000. All public elementary schools in Hamilton constituted the sampling frame and some 30 schools were randomly selected from four quadrants of the city to ensure an even geographic distribution of school children. Initial sample size considerations dictated 780 children per quadrant. Within each school, all children aged 7 to 10 years were selected for study. As designed, lung function in these children was to be measured in three consecutive years.

In order to determine the home environment and respiratory symptoms of the children, structured interviews were conducted with the parents of the child in the home. Subsequently pulmonary function of the children was determined by two teams of two pulmonary function technicians in the schools. Interviewing began in September, 1978 and the three interviews should be completed by October, 1981. Pulmonary function for Year 1 extended from December, 1978 to December, 1979, and Year 2 was completed at the end of 1980. Year 3 is scheduled to be completed by the end of 1981.

In parallel to the interviewing and pulmonary function testing in the children, total suspended particulates (TSP), particle size distribution (PSD), and sulphur dioxide (SO_2) are measured as indicators of air quality. There are now 27 TSP stations, 7 PSD stations and 16 SO_2 stations located primarily in relation to the schools and uniformly within quadrants. Particulate monitoring began in January, 1979 while SO_2 monitoring began in July, 1979.

Quality control of the data acquisition, coding, storage and analysis currently consists of (1) repeat interviewing by telephone of randomly selected questions from the structured interview, (2) repeat pulmonary function on a random 5% sample of children in each school, (3) comparing interviewer response rates and responses to individual questions, (4) comparing pulmonary function measurements between the two teams by parallel line regression analysis, and (5) double coding of a 5% random sample of pulmonary function forms. Other methods are being incorporated.

Interviews

The home interviews of the parents are randomly assigned to interviewers into geographic segments smaller than the quadrants and such that each interviewer moves around in the quadrants. The interviewers inquire about the child's respiratory health by asking questions about cough, shortness of breath, wheezing, lung oriented diseases, colds. In addition, aspects of

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* For further information contact Charlie Goldsmith, Urban Air Environment Group, HSC-3E27, McMaster University, 1200 Main Street West, Hamilton, ON, Canada, L8N 3Z5. Telephone: (416) 525-9140, Ext. 2434.

home environment such as number and type of rooms, number of people, number of people sleeping in same room as child, smokers in home, previous addresses and parental occupation and income were collected. At the end of the interview, consent for the child to participate in the pulmonary function test is requested.

Pulmonary Function Testing

Pulmonary function is measured on the children in the schools by two pulmonary function teams using two portable Hewlett-Packard 47804A pulmonary calculator systems. These teams produce reports consisting of age, weight, sex, height, race, forced vital capacity (FVC), forced expiratory volume in 1 second, mean forced expiratory flow between the 25 and 75% points of FVC, maximal expiratory flow after 50 and after 75% of FVC has been exhaled, time required to exhale from 25 to 75% of FVC, vital capacity; residual capacity, functional residual capacity, closing volume, nitrogen difference; as well as location, date and local environment information such as temperature, relative humidity, pressure, time.

Particulate Monitoring

TSP and PSD samplers are evenly distributed throughout Hamilton in the four quadrants in an attempt to monitor the load throughout the city. The TSP monitors are standard "Hi-Vol" samplers, using fiberglass filters and operating at 40 cubic feet per minute (cfm) for 24 hours on a six-day cycle. PSD measurements are obtained with similar units equipped with five-stage Anderson cascade impactors operated at a flow of 20 cfm. These six-day rotations usually permit about 60 runs per station per year. The filters are carefully weighed before and after exposure in a humidity and temperature controlled compartment on a standardized balance and the weights are used to estimate TSP and PSD with standardized procedures in micrograms per cubic metre.

SO_2 Monitoring

SO_2 is monitored at 16 base sites distributed evenly throughout Hamilton in the four quadrants. For six weeks of each season, monitoring instruments are placed in eight of the sites followed by a further six weeks in the second group of eight sites. The groups were chosen to provide coverage throughout the city at all times. Beckman SO_2 analysers (seven 906's and one 953) are located throughout the sites. A tunable diode laser has been constructed and calibrated to measure SO_2 in ppb concentrations. This portable laser device and a laboratory laser system are used to calibrate the Beckman instruments both in the field and in the service laboratory. Although hourly readings of SO_2 are available from the eight sites, means over days, weeks and months have been used so far in preliminary analyses. Another laser is currently being calibrated to measure NO_2, also in ppb concentrations.

Exposure Estimation

Standard regression techniques have been used to fit bivariate response surfaces to the air quality

measurements using the sampling station location in an East/West and North/South grid system as input. The air quality measurements fitted so far are monthly, seasonal and yearly means at the sampling stations for TSP and SO_2. Geometric means were used to combine the TSP measurements while arithmetic means were used to combine SO_2 measurements.

Explicitly, if X_1 is the standardized easting location, i.e., X_1 = (Easting location - 2600)/4000, and X_2 is the standardized northing location, i.e., X_2 = (Northing location - 2100)/2000, then models of the for

$$y = \beta_0+\beta_1X_1+\beta_{11}X_1^2+\beta_2X_2+\beta_{22}X_2^2+\beta_{12}X_1X_2+\epsilon$$

were fitted to the TSP and SO_2 data. The estimated coefficients for TSP by month, season and year are presented in Table 1.

Table 1

Estimated Response Surface Coefficients for TSP

Time Period	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_{11}$	$\hat{\beta}_2$	$\hat{\beta}_{22}$	$\hat{\beta}_{12}$	R^2
79:04	61.8	32.8	-19.9	70.3	- 78.4	43.3	.54
05	72.8	21.1	- 5.8	74.2	- 81.5	17.3	.36
06	94.1	16.3	25.2	75.6	- 75.6	26.7	.70
07	70.1	12.3	- 4.6	45.3	- 14.9	38.3	.83
08	69.1	10.1	- 4.9	35.2	- 43.5	68.2	.76
09	90.7	1.5	-59.7	65.5	- 77.4	102.1	.53
10	46.7	20.9	-37.2	57.5	- 54.1	89.3	.58
11	48.7	8.2	- 5.6	42.1	- 23.4	49.2	.70
12	44.2	8.6	-12.7	38.8	- 2.5	69.2	.70
80:01	66.6	30.8	63.9	-101.7	- 37.2	68.6	.61
02	68.5	42.4	65.0	- 90.0	59.4	125.9	.59
03	73.4	29.0	76.6	-107.4	-106.5	117.0	.58
04	68.4	28.6	82.6	-184.3	-105.2	83.3	.52
05	80.7	44.4	77.3	-182.9	- 57.3	76.3	.53
06	74.4	26.7	68.8	- 74.4	- 76.4	100.9	.57
79:07/09	69.5	32.1	74.3	- 74.8	- 73.2	49.9	.55
79:10/12	48.4	0.9	50.6	- 46.2	51.6	36.4	.55
80:01/03	50.6	16.0	49.2	- 77.7	- 36.0	97.7	.64
80:04/06	64.4	24.4	60.5	- 47.0	- 42.1	50.0	.54
79:07/80:06	64.4	24.2	61.8	- 34.9	- 58.1	71.4	.61

The coefficient of determination indicates that predominantly in excess of 50% of the variation in TSP responses during a month can be explained by the quadratic model in location. Other environmental characteristics such as wind direction and speed, temperature, rainfall, and pressure have not yet been considered in these models. Similar models were fitted to the SO_2 data but the explained variation as measured by the coefficient of determination were not as high, mostly above 30%.

Once a model has been developed, it is possible to estimate the exposure for that month (or other time period) at the school and home locations within the city. For example, for School Number 1 located at Easting = 3580 and Northing = 1965, the estimated TSP exposure for July 1979 was 69 ug/M^3. By using these estimates of air quality at specific locations for particular time periods, exposures could be individualized to school, home and possibly even a child measured at a particular time who spent π proportion of the time at school and $1-\pi$ proportion at home.

Quality Control

Using the Year 1 data and all of the Year 2 data

processed to the end of 1980, a random sample of questions indicated that 53/498 (11%) had some error comparing interview and random call back. Most of these errors were resolved or not considered to be a problem. Some were possibly real changes in health status of the child since they were often asking about a quite different time period. No significant differences have been found attributable to the interviewers.

The reproducibility of some of the pulmonary function measurements is shown in Table 2.

Table 2

Pulmonary Function Reproducibility

Variable	Year 1		
	Cases	t	P
CV/VC	166	1.42	.158
FEV1	216	1.33	.185
FVC	216	-3.96	.001
MEF50	215	3.57	.001
RV	213	0.33	.739
MET	215	-3.13	.002

Although the differences in FVC, MEF50 and MET are considered to be small, the fact that they are not reproducable has led to investigation of the reasons for these differences. So far they have been attributed to practice effects in the child.

Coding of lung function data resulted in error rates of between 0.44 and 2.07%, while questionnaire coding error rates have been less than 0.29%. Keypunching error rates are so low they can be considered to be zero. Range checks at data storage time have varied between 0.001 and 3.6%, most of which were easily resolvable.

Each of the pulmonary function teams had similar missing value rates varying from 0.9% for FVC to 27.9% for the nitrogen differences. These rates have reduced from Year 1 to Year 2 and there are no significant differences by team.

Using parallel line regression analysis to determine the linear model of FVC by height for each team indicated that the straight line models were adequate for each team [A: $F(7,309)=0.86$, B: $F(5,138)=1.97$], parallel [$F(1,497)=0.01$] and not quite coincident [$F(1,510)=8.09$] in Year 1.

Response Rates

For each quadrant of the city in Year 1, there were 867 (west upper), 374 (east upper), 737 (west lower) and 825 (east lower) interviews completed; all in excess of the 780, the required sample size and in excess of 94% of those approached and in Year 2 in excess of 94%. For the first 17 schools in Year 2, in excess of 80% have been retested by quadrant and 1823/2109 (83%) overall. In Year 2 there were 345 new children added. If Year 3 is as successful, some 80% of the initial sample should have three consecutive measures and some 12% more should have two consecutive measurements of pulmonary function.

Acknowledgements

The authors express their deepest gratitude to our wonderful staff who are a pleasure to work with and have made this study possible. Financial support is gratefully acknowledged from Health and Welfare Canada (6606-1752-33), Ontario Ministry of the Environment, Air Resources Branch (78-020-33) and the Ontario Ministry of Health, Public Health Grants (CHS-R34).

APPENDIX 1-2

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AIRFLOW OBSTRUCTION IN CHILDREN AND ITS RELATIONSHIP TO QUESTIONNAIRE DATA.

A. T. Kerigan, L. D. Pengelly, and C. H. Goldsmith, Departments of Medicine, and Clinical Epidemiology and Biostatistics, Mc Master Univerity, Hamilton, Ontario, Canada

Yearly measurements of pulmonary function and questionnaire data relating to respiratory symptoms and family characteristics are being obtained on 3200 children, aged 8-11, in a 3 year study in Hamilton, Ontario relating respiratory health to environmental factors. Using an FEV_1/FVC ratio less than 70% as evidence of airflow obstruction (AO), 4.2% had AO in Year 1, and 5.2% in Year 2. 1.8% of the total sample had AO in both Year 1 and Year 2. The questionnaire responses of this subgroup with persistent AO were analysed to determine if there were distinguishing characteristics which might predict those children with AO in the general population. For those questions relating to wheezing and to asthma in the previous year, there were significantly ($p < 0.001$) more children with AO in these categories. In addition, when the numbers of smokers in the child's household were examined, there were significantly (p 0.02) more children with AO in those homes with more than 2 smokers. The predictive ability of these three features for AO were asthma (7.2%), wheezing (3.6%) and more than 2 smokers (5.9%). There was no relationship between AO and any other respiratory symptom, the occurrence of early childhood respiratory illness, respiratory illness in other members of the family or other characteristics of the dwelling. In view of the potential of these children with persistent AO to develop chronic respiratory disease as adults, their identification in childhood becomes important and further measurements of their pulmonary function in Year 3 of this study will be of value in identifying those children at risk in the general population.
(Supported by Health and Welfare, Canada and Environment Ontario.)

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APPENDIX 1-3

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AIR QUALITY AND ITS EFFECT ON THE RESPIRATORY HEALTH IN SCHOOLCHILDREN: A STUDY IN HAMILTON, ONTARIO. 1978-1981:

A. T. Kerigan, B. K. Garside, C. H. Goldsmith and L. D. Pengelly; Mc Master University, Hamilton, Ontario Canada.

A three year study, ending in December 1981, is being undertaken of the effect of air quality on the respiratory health of schoolchildren. All children, aged 7-10, attending schools randomly selected within each of four quadrants of the city were selected. Participation rate has exceeded 95%, the total number studied in Year 1 being 3,200 and the follow-up rate in Year 2 has been 85%. Each year, the home environment and presence of respiratory symptoms are measured by an interviewer administered questionnaire. Pulmonary function testing (PFT), including single breath nitrogen washout is conducted in the schools by two teams using Hewlett-Packard 4780A systems. The quality of this data is evaluated in terms of a) bias by comparing both interviewer responses to individual questions and PFT measurements between the two teams and b) reproduceability by repeat interviewing of randomly selected questions and repeat PFT on a random 5% of children. Outdoor air quality is measured by 16 total suspended particulate (TSP) stations and 24 sulphur dioxide (SO_2) stations sited uniformly within the quadrants. From these point measurements, a bivariate quadratic response surface model has been fitted for each month with location as input and each of TSP and SO_2 as output. These models have enabled the estimation of exposures to be made for the actual school site or home. Earlier measurements had shown gradients across the city for both TSP and SO_2 and first year study measurements have confirmed these, TSP ranging from 43 to 94$\mu g/m^3$ annual geometric mean. Indoor air quality is being assessed qualitatively in terms of smoking and gas cooking and will be measured quantitatively in Year 3. Analysis of Year 1 data has shown a highly significant ($p < 0.001$) association between outdoor air quality in terms of high or low TSP and other factors associated with increased respiratory morbidity such as number of smokers in household of child, gas cooking, income and number of persons sharing the child's room. (Supported by Health and Welfare, Canada and Environment Ontario.)

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APPENDIX 1-4

ONTARIO MINISTRY OF THE ENVIRONMENT
28TH ONTARIO INDUSTRIAL WASTE CONFERENCE
JUNE 14-17, 1981 PRINCE HOTEL, TORONTO

EFFECTS OF THE BREATHING ENVIRONMENT ON THE RESPIRATORY HEALTH OF SCHOOL CHILDREN IN HAMILTON, ONTARIO

L.D. Pengelly, A.T. Kerigan, C.H. Goldsmith, and B.K. Garside,
Departments of Medicine, Clinical Epidemiology, and Biostatics and Engineering Physics; McMaster University, Hamilton, Ontario.

Hamilton, Ontario is an industrial city which has reduced its ambient air pollution by an order of magnitude in the last two decades. There remains a concern on the part of its citizens that the current levels of air pollution have a negative health effect. We are currently in the third year of a four-year study we initiated to examine the effect air pollution has on the respiratory health of children (initially aged 7 to 10 yr.), and to put this in the context of other factors, e.g. parental smoking, socioeconomic, housing, etc. Our multidisciplinary group is responsible for carrying out all phases of the study, including measurement of ambient outdoor and indoor air quality, questionnaire survey, pulmonary function testing and data analysis. Three thousand three hundred children were studied in the first year (response rate more than 96%) and 85% of those children were restudied in the second year. Initial results show steep gradients in air pollution levels over the city, but these are also accompanied by similar gradients in socioeconomic levels and parental smoking habits. We are investigating analytical techniques to be used to isolate effects of the separate factors.

APPENDIX 3-1

REVISED SMOKING QUESTIONNAIRE

5

6

Please complete this form by placing an "X" in the correct box.

No one will know whose form this is, it is a secret.

FOR OFFICE USE ONLY

1. Have you ever smoked?

☐ YES ☐ NO

30

IF YOUR ANSWER TO QUESTION 1 IS NO, **DO NOT** ANSWER ANY MORE QUESTIONS.

2. Have you smoked in the last four weeks?

☐ ☐

31

IF YOUR ANSWER TO QUESTION 2 IS NO, **DO NOT** ANSWER ANY MORE QUESTIONS.

3. How many cigarettes do you usually smoke in a week?

☐ less than 1 ☐ 1-10 ☐ more than 10

32

4. At what age did you smoke your first cigarette?

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12

33 34

☐ 13 ☐ over 13

APPENDIX 3-2

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L. D. Pengelly
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ive meeting and date previously presented _____
nces if published _____

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ou, s'il y a eu publication subséquente, donnez les références _____

NGLE-BREATH NITROGEN WASHOUT AS AN EPIDEMIOLOGICAL SURVEY TOOL IN CHILDREN

L.D.Pengelly, A.T.Kerigan, E.M.Inman,
McMaster Univ. Dep't. of Medicine,
Hamilton, Ontario, Canada.

e Single-breath Nitrogen Washout (NWs) has been used as an epidemiological ol in a study of children (9-10 yr) by Becklake et al (Bull. europ. Physio-th. resp., 1978,14,205). We are studying respiratory health in school ildren aged 7-10 yr. Pulmonary function is measured by an automated sys-m (HP 47804A) in the schools. Indices of pulmonary function are derived om several manoeuvres, including the NWs. We have examined the ability of e child to carry out a successful manoeuvre according to our criteria, and e reproducibility of results when strictly controlled manoeuvres are peated, both for the NWs and for the FVC. Results are given in the tables. e success rate for the NWs is far below that for the FVC, and is highly e-dependent. Reproducibility of CV/VC and FEV1/FVC was examined in a sub-t of the children, who were each tested 6 times. The range of the coeffi-ent of variation for each manoeuvre shows that measurements derived from e NWs are much less reproducible than those from the FVC.

	SUCCESS RATE (PER CENT)					
GE(yr)	6	7	8	9	10	11
(N)	(12)	(574)	(1033)	(936)	(509)	(68)
EV1/FVC	100	98	94	98	99	97
/VC	50	56	74	81	89	88

COEFF OF VAR (RANGE)			
FEV1/FVC	1%	-	15%
CV/VC	25%	-	99%

upported by Canada: Health and Welfare; Ontario: Environment, and Health.

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APPENDIX 3-3

CARD 3 - YEAR 3

SURVEY OF RESPIRATORY FUNCTION STATUS OF CHILDREN

I.D. [ ][ ][ ][ ][ ] 1 5

CARD [3] 6

ROOM [ ][ ][ ] 7 9

AGE [ ][ ] 10 11

WEIGHT [ ][ ][ ] 12 14

SMOKER [ ][ ] 15 16

TEMPERATURE [ ][ ] 17 18

HUMIDITY % [ ][ ] 19 20

SEX [ ] 21

HEIGHT [ ][ ][ ] 22 24

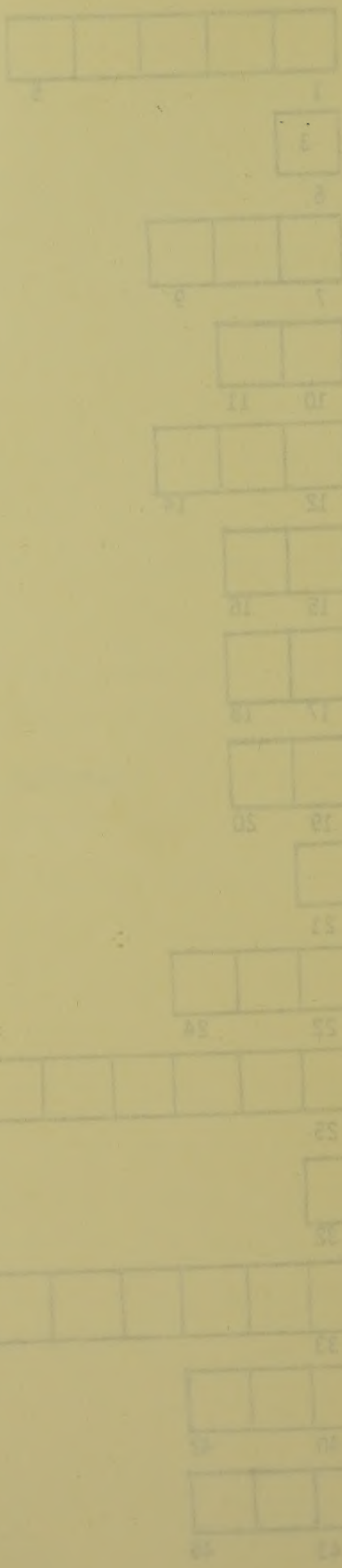
RACE/BIRTH [ ][ ][ ][ ][ ][ ][ ] 25 31

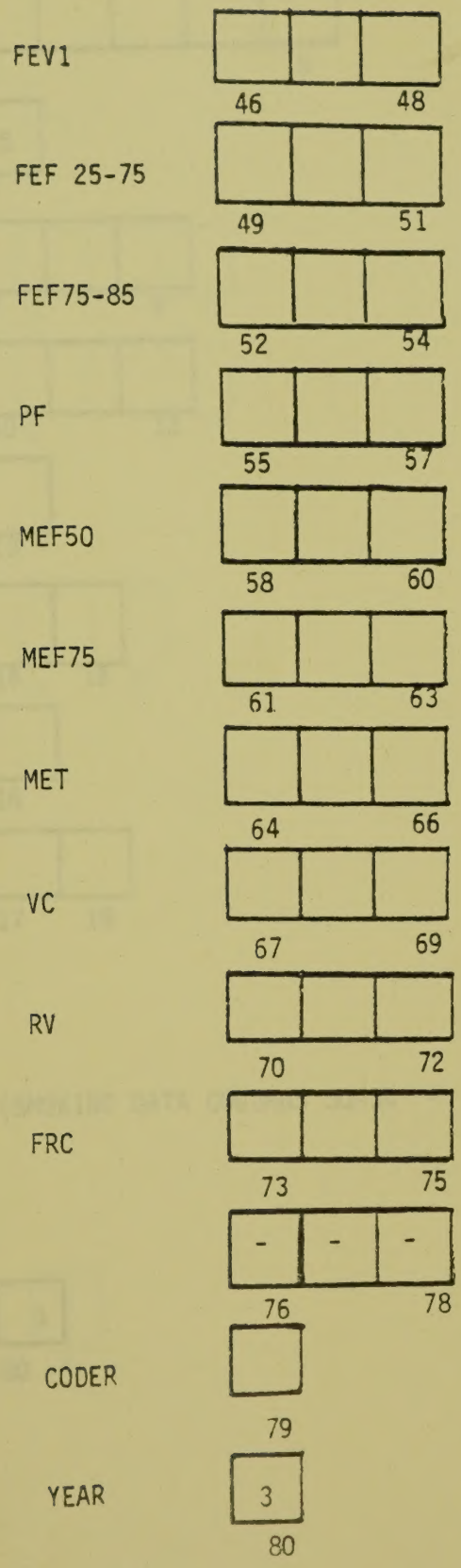
TESTER [ ] 32

DATE/TIME [ ][ ][ ][ ][ ][ ][ ] 33 39

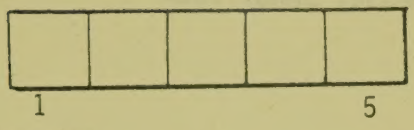
PRESSURE [ ][ ][ ] 40 42

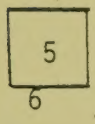
FVC [ ][ ][ ] 43 45

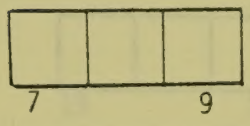


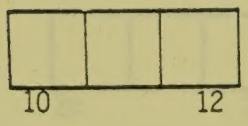

FEV1
46 48
FEF 25-75
49 51
FEF75-85
52 54
PF
55 57
MEF50
58 60
MEF75
61 63
MET
64 66
VC
67 69
RV
70 72
FRC
73 75
- - -
76 78
CODER
79
YEAR
3
80

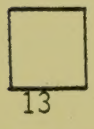
CARD 5 - YEAR 3

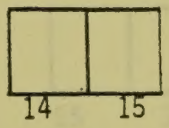
I.D. 

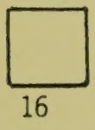
CARD 

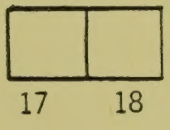
ADS 

IDI 

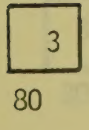
SPIRERR 

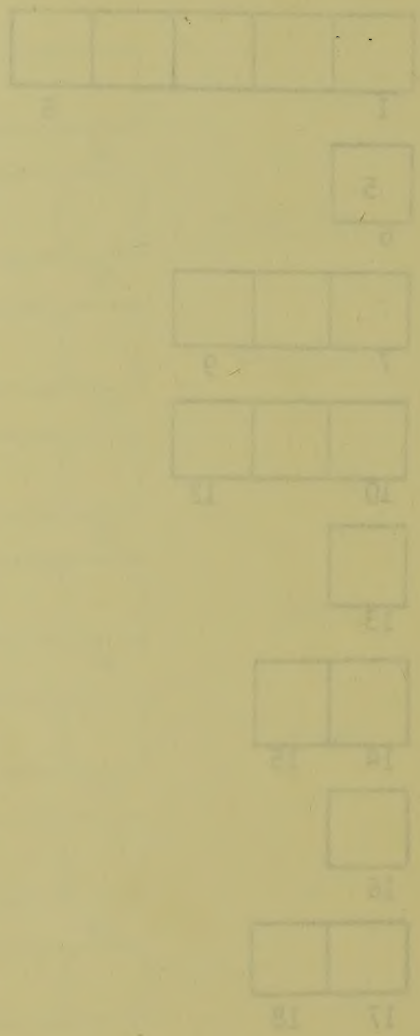
COLDWHEN 

COLDNOW 

SKOLAT 

(SMOKING DATA COLUMNS 30-34 - Page 2)

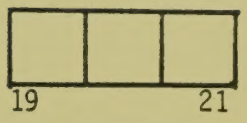
YEAR 



CARD 5 - Year 3

ADDITIONAL INFORMATION

FRC 2



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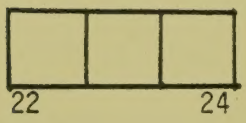
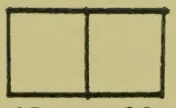
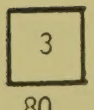


QUALITY OF TEST



YEAR



APPENDIX 3-4

PROTOCOL AND CRITERIA TO BE USED BY THE PULMONARY FUNCTION TESTERS IN THE SCHOOLS

Year 3 - January 1981

PROTOCOL

1. Each child is instructed before each test as to what is required.

2. The order of the tests is as follows. NWm x 1, FVC x 3, Spirometry x 1. As of February 1981, for a limited period, until 500 children have been so tested, a second NWm is obtained at the end of testing.

3. The tester ensures that the child is relaxed, that lips are sealed, and the noseclip is on properly.

4. NWm - This test is done with the child seated. Tidal breathing must be quiet, relaxed, and regular when on the mouthpiece. When the child is ready the computer is switched in. The N_2 must be falling; if not, the test will be invalid. The child continues to breathe quietly until less than 1% N_2 is detected. The machine will stop automatically at about 0.8%. If the initial N_2 readout on the computer display is less than 68% the test is invalid and must be repeated after a rest.

5. FVC - The child stands, non-supported (not leaning). The child breathes in room air to TLC, inserts FVC pneumotach, with a clean sterile

mouthpiece into the mouth, and gives a forced expiration as rapidly as possible to RV followed by a forced rapid inspiration back to TLC. The expiration must last for at least one second for the machine to record results.

6. Spirometry - This is done with the FVC pneumotach and the child seated. The child breathes quietly into the mouthpiece until the tester is satisfied with the relaxed VT, and switches in the computer. After four quiet VT breaths a maximum inspiration to TLC and expiration to RV is made. Quiet breathing is continued for three breaths to re-establish a stable FRC which should return to the pre-VC baseline.

7. A short report is asked for all children. If parents have asked for results or if the child has low results (see criteria) a long report to the end of the FVC plot is asked for.

CRITERIA

GENERAL

Great care must be taken to ensure a good seal at the mouthpiece also that the child is relaxed and makes a maximum effort.

SPECIFICS

NWm

Normal tidal breathing is essential. Test must be repeated if the initial N_2 is less than 68% and if the final N_2 is greater than 1%. While two tests are obtained, the test selected for inclusion in the project data is the one which has the least deviation from an estimated line of best fit, i.e. the least scatter. If this is the same for the two tests, the selected test will have the highest initial N_2 reading.

FVC

The two best VC's must be within 5% of each other. However, if the tester has done up to six attempts, with only one good VC resulting (the others are not within 5%), then the one good VC is still acceptable. If $FEV_1/FVC < 70\%$ a long report is needed.

Spirometry

This VC is compared to the best FVC; if less than 10%, the Spirometry is repeated, if more than 10%, the FVC is repeated. If ERV is less than 20% and more than 50% of VC, then the test must be repeated. FRC must be stable.

COMMENTS

Children with colds or hayfever must have this data entered under "comments". Heavy broncial lower chest colds are entered as "lower resiratory heavy", sneezing, dry coughing and upper chest colds are entered as "upper respiratory

heavy", and sniffles as "slight cold".

Any medical information concerning the child and known to the tester, e.g. asthma, should be entered also.

PROTOCOL AND CRITERIA TO BE USED BY THE CODERS OF PULMONARY FUNCTION DATA

Year 2 - January 1981

PROTOCL

1. The two assistant technicians code the Pulmonary Function Data. This is done in the schools immediately after each child is tested.

2. When all coders have completed 20 tests, a randomized quality control is done.

CRITERIA

1. Patient Data - Information on the report must agree with the information slip for each child.

2. NWm - The initial N_2 concentration must not be less than 65% and must fall continuously to not more than 1%.

3. FVC - This must be within 10% of the biggest VC obtained on any test.

4. Spirometry - VC must be within 10% of biggest. FRC must be stable, i.e. the baseline must not deviate by more than 200 ml (by eye). FRC after

VC maneuver should be approximately the same as before the maneuver. If the machine has chosen an incorrect FRC, the coders will correct this, recalculate the ERV and IC and adjust the RV and TLC values accordingly.

CHECK OF THE DATA AT MCMASTER

BEFORE KEYPUNCHING

Year 3 - 1981

1. All data is looked at by Supervisor to check the acceptability of the tests.

2. All data is ordered, listed and checked against original school lists to ensure accuracy of numbers.

3. Coded data sheets are matched with coded information regarding smoking status and given to Data Analyst.

APPENDIX 6-1

Very High Sensitivity Spectroscopy using Tunable Diode Lasers

John Reid and Brian K. Garside, Department of Engineering Physics
McMaster University, Hamilton, Ontario, Canada L8S 4M1

Abstract

We describe a laser absorption spectrometer which employs a tunable diode laser to detect infrared absorption coefficients as small as 10^{-9} cm^{-1}. Applications to atmospheric spectroscopy are discussed.

Very High Sensitivity Spectroscopy using Tunable Diode Lasers

John Reid and Brian K. Garside, Department of Engineering Physics
McMaster University, Hamilton, Ontario, Canada L8S 4M1

In recent years, tunable diode lasers have become widely used in the study of laboratory infrared spectra. The high resolution provided by the diode lasers is employed to obtain accurate line positions, and to a lesser extent lineshapes and linestrengths. While this type of research is now undertaken in many laboratories, few researchers are currently exploiting the potential of the diode lasers to provide very high sensitivity measurements in the infrared. In this paper, we describe diode modulation techniques which enable one to detect absorption coefficients as small as 10^{-9} cm^{-1}. This sensitivity, combined with the tunability and resolution of the diode laser, allow one to perform a wide range of experiments relevant to atmospheric spectroscopy. In the laboratory one can detect very weak absorption lines in stable molecules [1], or investigate the spectra of unstable molecules such as free radicals [2]. The instrumentation is portable, and we have used it to make in situ field measurements on a wide range of gases and pollutants in an urban atmosphere [3]. Similar instruments have been flown in aircraft to monitor tropospheric CO concentrations, and balloon flights are planned to simultaneously determine stratospheric NO_2 and NO concentrations [4].

In our laser absorption spectrometer (LAS), the diode laser is used in conjunction with a multipass optical cell. The laser is generally operated in a single mode which is tuned across strong absorption lines in the molecule under investigation. Second harmonic detection techniques are used to acheive high sensitivity [3]. Figure 1 shows typical results

obtained while detecting NH_3 in air. The sensitivity of the LAS is limited by "optical" noise caused by Fabry-Perot type fringes formed in the multipass cell. As shown in Figure 2, this type of noise can be substantially reduced by using a second "jitter" modulation of the diode laser current. Full details of this technique will be presented. In a 1 m multipass cell,

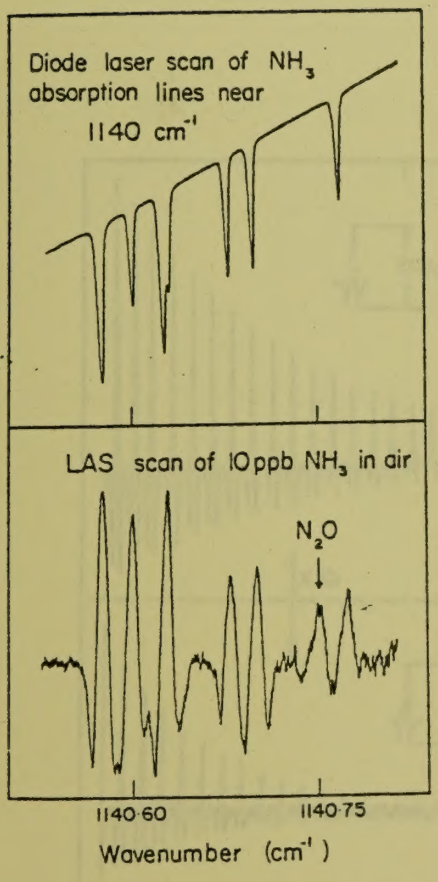


Figure 1: High resolution diode laser spectra of NH_3 lines near 1140 cm^{-1}. The upper trace was taken with conventional amplitude detection using a 10 cm sample cell containing < 1 Torr NH_3. The lower trace was taken with second harmonic detection through a 200 m pathlength in air at 20 Torr. In addition to the NH_3 lines, the air scan also contains lines due to N_2O.

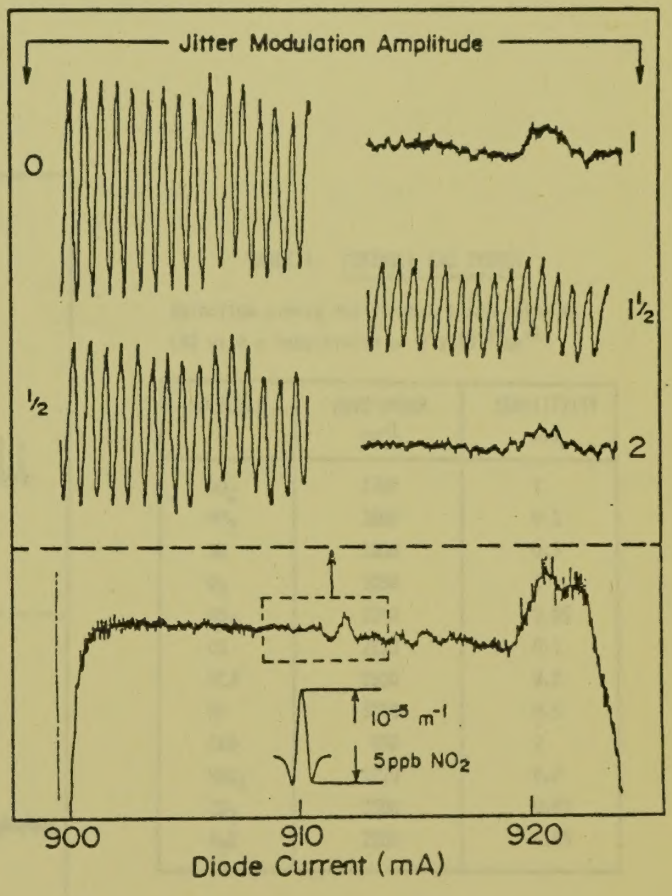
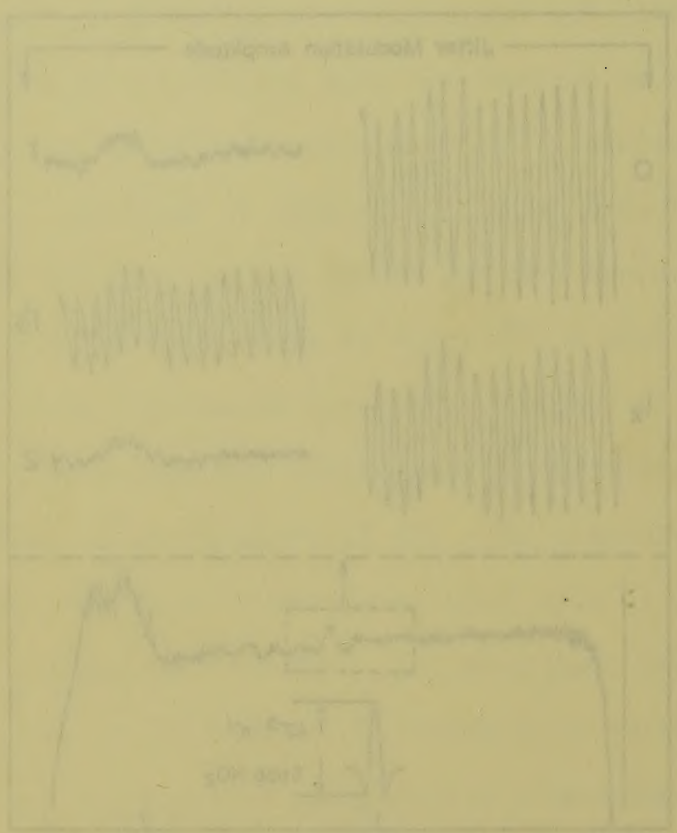
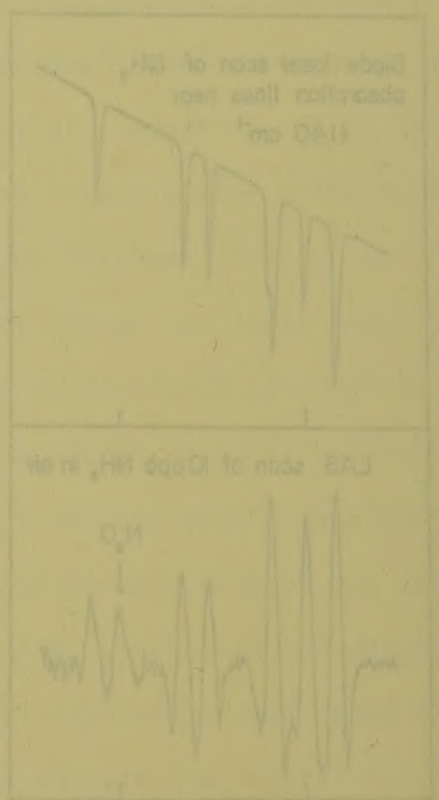


Figure 2: Effect of adding a "jitter" modulation to the diode current. For these scans the multipass cell is set for 40 m absorption and the fringes are caused by interference between the main optical beam making 40 passes through the cell and the much weaker beams which make 36 (or 44) passes. The lower trace is taken with the jitter amplitude set at 1 fringe spacing, and a second harmonic lineshape corresponding to ~5 ppb NO_2 (or 10^{-5} m^{-1} absorption coefficient) is also shown to indicate sensitivity. Note the significant improvement in sensitivity as the fringes are electronically "washed out".





the resultant noise using optimum jitter is equivalent to an absorption coefficient of 1 to 2 x 10^{-9} cm^{-1}. Details will be presented of the LAS calibration procedure, and also the techniques used for continuous monitoring of pollutants. Figure 3 shows the continuous monitoring of NO_2 concentration as the gas reacts in a stainless steel cell. The sensitivity demonstrated in Figure 3 illustrates the potential of diode lasers for monitoring gas kinetic reactions in the range of gas concentrations typically found in the atmosphere [5].

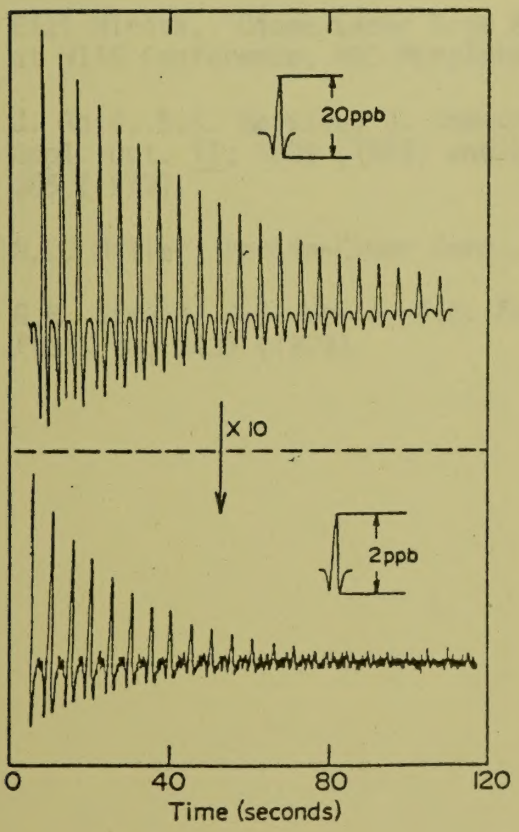
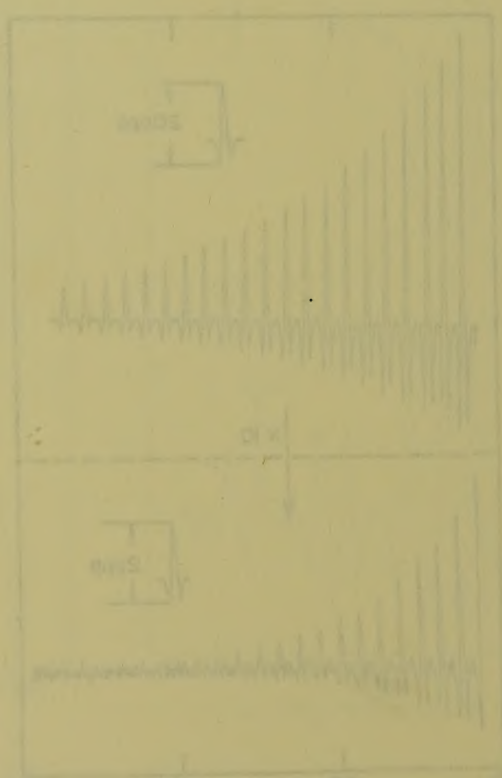


Figure 3: Lifetime measurement of NO_2/air mixtures in a stainless steel multipass cell. The LAS was set to scan repetatively over a strong NO_2 doublet at 1604.162 cm^{-1}, and the cell was filled with air plus a trace of NO_2 at ~30 Torr total pressure.

TABLE I: PORTABLE LAS SYSTEM

DETECTION LIMITS FOR SEVERAL GASES USING AN LAS WITH A SENSITIVITY OF 2 x 10^{-9} CM^{-1}

MOLECULE	WAVENUMBER CM^{-1}	SENSITIVITY PPB
SO_2	1350	1
NO_2	1600	0.1
NO	1800	0.3
O_3	1050	1
NH_3	1040	0.05
CO	2120	0.1
HCℓ	2900	0.2
HF	3700	0.5
ClO	850	2
HNO_3	1720	0.2
CO_2	2300	0.01
N_2O	2200	0.05



The versatility of the LAS is illustrated in Table 1. This table lists many gases of atmospheric significance, and the detection limits of the LAS for each gas. Results will be presented for several of these gases, both to illustrate the LAS sensitivity, and the instrument's freedom from interference from unwanted molecular species.

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